Guidance on the construction of SuDS



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CIRIA C768 London, 2017

Guidance on the construction of SuDS

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Summary

Over recent years SuDS delivery in the UK has steadily increased. This has improved knowledge and experience, particularly around the construction of SuDS. This guide uses that experience to help those who are constructing SuDS to understand and avoid common pitfalls.

The guide starts with considering SuDS in the construction planning and management of a site. It discusses the construction of different SuDS components, using photographs of actual site works to illustrate both good practice and what can go wrong. Case studies are provided to show how good construction has been achieved or problems resolved.

Guidance on the construction of SuDS

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CIRIA

C768 © CIRIA 2017 RP1028 ISBN: 978-0-86017-783-8

British Library Cataloguing in Publication Data

A catalogue record is available for this book from the British Library

Keywords	
Sustainable drainage, construction, inspection, planning, site management, materials, specification, design, pre-construction, environmental good practice	
Reader interest	**Classification**
SuDS design can be misinterpreted and fail because of poor construction and detailing. Guidance and recommendations on construction of SuDS will ensure they are built as designed, to provide the performance and benefits required. This will lead to increased confidence in SuDS as a mainstream approach to surface water management and drainage design.	Availability: Unrestricted Content: Technical guidance Status: Committee-guided User: Clients (developers, local authorities, sewerage undertakers), contractors, consultants, practitioners and others with an interest in construction sites, ie site managers, clerks of work, resident engineers

Published by CIRIA, Griffin Court, 15 Long Lane, London, EC1A 9PN, UK

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Acknowledgements

This publication is the result of CIRIA Research Project (RP) 1028.

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Isaac Winchcombe	Illman Young Landscape Design
Bridget Woods-Ballard	HR Wallingford

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How to use this guide

This guide is specifically designed to assist those people constructing, managing, inspecting or approving sustainable drainage systems (SuDS) construction on site. It provides easily accessible information about all aspects of SuDS construction, and enables the information specific to each SuDS component to be downloaded as an individual chapter. More in-depth technical guidance on SuDS can be obtained from **The SuDS Manual CIRIA C753** (Woods Ballard *et al*, 2015), which is available to download from: **www.ciria.org** or **www.susdrain.org**

To make the guidance more relevant, photographs of actual site works have been used where possible to illustrate both good practice and what can go wrong. Case studies show how problems have arisen on site, and how they have been overcome.

Within the guide the following boxes have been used to assist the reader:



Hold point

Identify points in the construction process where the works should be inspected before continuing with their construction.



Watch point

Identify potential problems to be particularly aware of as they frequently occur on site.



Handy hint

Anticipate problems, so they can be avoided, or offer a simple solution to a common problem, which may be useful.

Jargon buster

This is included at the end of each chapter to explain any technical terms to those who may be unfamiliar with SuDS terminology.

This guide complements **CIRIA C753**, which provides comprehensive information on the planning, design, construction and maintenance of SuDS.

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A Introduction





1 WHAT ARE SUDS?

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Chapter 1

What are SuDS?

This chapter is an introduction to SuDS. It explains why and how SuDS construction needs a different approach to traditional drainage.

1.1 THE SUDS APPROACH

Sustainable drainage aims to imitate the natural drainage of a site before development. Sustainable drainage systems (SuDS) give equal consideration to controlling water quantity, improving water quality, providing opportunities for amenity and improving biodiversity. Similar to a natural catchment, a combination of drainage features (also known as components) work together in sequence to form a management train. The management train controls both flows and volumes, as well as treating surface runoff to improve water quality. The fundamental principle is to slow down the movement of surface water runoff, or encourage it to infiltrate into the ground, to reduce its impact further down the catchment.

Instead of draining water underground in piped systems, SuDS provide the opportunity to create attractive places and visible routes for rainwater to permeate the built environment and connect people with water. Drainage components on the surface provide valuable wildlife habitat and increase biodiversity as well providing opportunities for education. SuDS can be designed to fit all developments and infrastructure projects, as there are a wide range of components available to meet each site's specific requirements, opportunities and constraints. This applies to new-build schemes and retrofitting SuDS to existing developments or urban spaces. They can be either hard constructed systems or soft landscaped features, ranging from permeable paving or small, hard edged water features to large-scale ponds and dry detention basins, as well as more engineered components such as green roofs and below ground attenuation storage systems. Many SuDS components use a combination of both hard and soft landscape features.

More detailed information on the planning, design and maintenance of SuDS can be obtained from **The SuDS Manual, CIRIA C753** (Woods Ballard *et al*, 2015).

1.2 WHY SUDS NEED CARE IN CONSTRUCTION

Even when SuDS are designed as simple, shallow features, they still require careful construction (like pipes) to ensure that they will fulfil their design requirements. SuDS are not difficult to construct, but are different to traditional drainage and need a good understanding of what is required by those building them. A lack of understanding of the different construction approaches required for SuDS can easily result in avoidable mistakes and their underperformance or even failure. Where SuDS appear to be simple landscape features, there is often an underestimation of the need for precision to ensure they meet the design criteria, or indeed, what those criteria mean in terms of the practicality of delivering the project on the ground. The phasing of the works, management of site activities, and factors such as site conditions, particularly the control of sediments and pollution, are all a critical part of successful SuDS construction.

Jargon buster

- A **catchment** or natural catchment is an area of land within which all runoff is directed to. All runoff falls by connected routeways to a single discharge point.
- A **component** is a drainage feature that can take many different forms.
- **Surface water runoff** is the water that runs off a surface such as a roof or car park into the drainage system. In this guide the term water is generally used instead of surface water runoff to make it easier to read.
- **Traditional drainage** is designed to remove water from a site as quickly as possible using pipes. Rainwater is seen as a problem to be removed and there is no consideration of using the rainwater or the drainage system to provide additional benefits such as biodiversity or improving the landscape.



2 WHAT MAKES SUDS DIFFERENT?

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Chapter 2

What makes SuDS different?

This chapter explains the difference between traditional drainage and SuDS and why the approach to their planning and construction needs to be different.

- *See Part C on construction planning and programming.*
- *General good practice guidance on the construction of SuDS can be found in The SuDS Manual (CIRIA C753).*

2.1 INTRODUCTION

The traditional approach to drainage

Surface water drainage has traditionally been designed using only underground pipes and storage systems. These were designed to improve public health and to protect properties from flooding, by quickly removing water from an area. However, many older surface water systems drain to combined surface water and foul sewers that were not designed to accommodate today's volume of rainwater. Consequently, when extreme rainfall occurs and the drains surcharge, foul sewage can flood urban areas. Modern surface water systems are separated from foul sewage, and generally discharge into watercourses, but if they overflow it can lead to flooding or pollution.

The SuDS approach to drainage

SuDS provide the opportunity to manage surface water runoff from developed areas in a cost-effective way that manages local flooding and protects the environment. They also deliver a range of benefits to the surrounding environment. Traditional drainage systems have a finite capacity, and are designed solely to address water quantity. While it is important to control both runoff volumes and flows to prevent downstream flooding, SuDS can also offer the following additional benefits to the surrounding environment as an inherent part of their design:

- Reduce runoff volumes and flow rates in existing surface water systems to help prevent flooding (or provide capacity to accommodate new development without increasing flood risk).
- Improve water quality where the water passes through green planted systems, or through hard or proprietary SuDS components that are designed to reduce the silt and pollution in runoff.
- Enable groundwater to be recharged using infiltration systems, where appropriate.
- Provide attractive amenity spaces or landscape features as an integral part of existing urban spaces or new development.
- Improve biodiversity by contributing to green networks and corridors, and creating a range of habitats for wildlife.

Constructing SuDS can appear simple, but they are also subject to technical design considerations and standards in the same way as traditional piped systems. Understanding the critical issues when constructing and delivering each different component, is crucial. The SuDS designer has an important responsibility in ensuring that SuDS components are designed for ease of construction and maintenance and that their functionality is fully explained to those constructing and maintaining the SuDS.

2.2 THE RANGE OF SUDS

Most traditional drainage approaches are similar, although the scale changes between schemes. SuDS have wider design objectives and use a range of components in addition to pipes and tanks. While many SuDS schemes take a simplistic approach (mainly using swales and ponds, or underground tanks), there are a wide range of SuDS components that can be used in a variety of ways. These can be adapted to suit every situation, as decided by each designer. The full range of SuDS components and the challenges around their construction are discussed in **Part F**.

2.3 WHY SUDS CONSTRUCTION IS DIFFERENT

How construction planning can affect SuDS

Early consideration of SuDS in the construction planning process is important to ensure the schemes' successful delivery. Construction planning on any site is influenced by many factors that are not generally linked to SuDS, but could significantly affect their construction or function. These include:

- vehicle access around the site during its construction
- site management for efficient construction
- location of the temporary site facilities
- location of cranes and heavy plant or machinery
- storage of materials
- the need to provide or maintain services to the site or retain buildings during construction
- phasing or sequencing of the works
- managing surface water runoff during construction
- cut and fill across a site to establish new levels, and the short- and/or long-term storage of soils.

Environmental issues both on- and off-site can add further legislative and practical constraints so must be considered during the planning of SuDS construction:

- restrictions on works or access around archaeological features, trees or habitats designated for retention to avoid damage to them
- maintenance of existing watercourses
- prevention of pollution
- prevention of downstream flooding caused by the construction works
- seasonality of planting works.

The client may also influence the sequencing of works on site, by requiring particular parts of the site to be delivered early.

Many of these constraints can also affect the ability of the SuDS to be built and maintained in good condition throughout the construction of the works – the potential for them to be damaged through site pollution, compaction or other causes is high.

How SuDS can affect construction planning

Construction of pipes and subsurface tanks follow well-established procedures (eg pipe gradients, bedding materials, type of backfill and cover depths). Piped drainage is usually constructed early in the programme before roads are constructed. Development can then proceed above the piped system, which is used to drain the site roads during construction.

There is a regulatory requirement to ensure that water discharged from site during the construction process is free from silt and pollution (see **Part D Chapter 13**). Traditional drainage schemes have advantages in being (mainly) simple pipe and tank systems, where water can be easily stored during construction. These systems can often be easily cleaned or rodded to restore their functionality.

For SuDS that are surface components the levels, slopes and soil structure are crucial to their performance. Although SuDS can still be constructed early in the programme, they may have exposed surfaces, materials and vegetation that are prone to clogging by mud or silt. Building construction needs careful integration with drainage construction to avoid damaging them.

Soft (planted) SuDS or SuDS where water infiltrates through pervious paved areas cannot be as easily restored as traditional drainage, and can be both expensive and time-consuming to rebuild, replant or clean if affected by polluted or silt-laden runoff. However, SuDS can be used to manage construction runoff if designed to do so and where the cost and time to restore them at the end of the project has been planned.

SuDS generally require the land on which they are constructed to be isolated from the construction process (see **Part D Chapter 12**), to prevent damage through compaction, pollution, erosion, silt or sediments, which can either kill planting, or clog the systems. Vegetated SuDS require the planting to be sufficiently established before being used, so they are not damaged by the erosion of unplanted areas. These factors can significantly affect how the phasing of the site works is planned (see **Part C Chapter 8**).

Considering SuDS construction requirements at the start of the construction planning process is important and will ensure that they can be successfully delivered.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Drainage surcharge** occurs when the amount of water flowing in the system is greater than its capacity. Water overflows from the drainage system onto the surface and can cause flooding.

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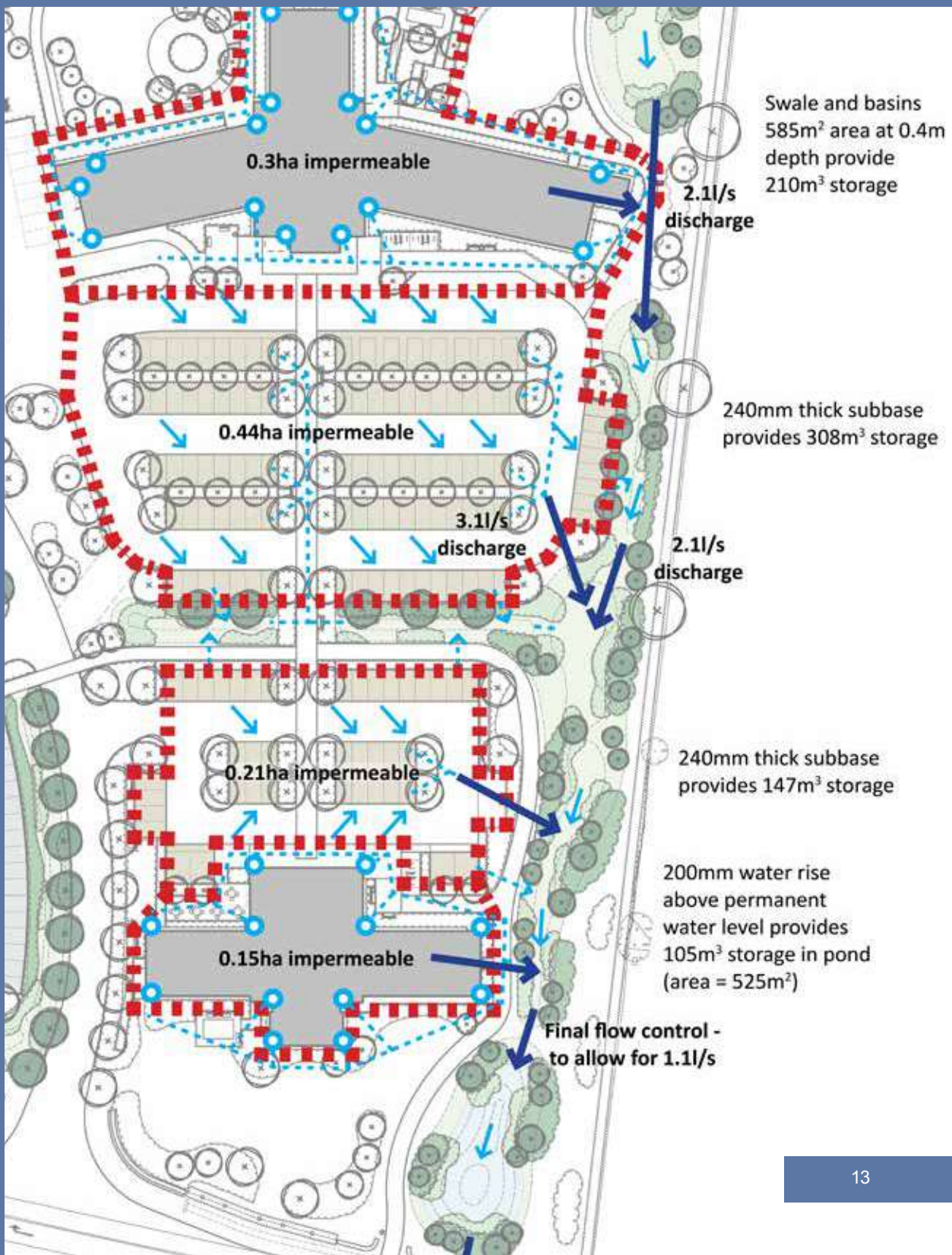
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3 BASELINE INFORMATION

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Chapter 3

Baseline information

This chapter provides baseline information that should be understood as part of the pre-construction planning stage.

- *A pre-construction checklist is provided in Part B Section 6.2.*
- *General good practice guidance on the construction site planning and management of SuDS can be found in The SuDS Manual (CIRIA C753).*

3.1 INTRODUCTION

It is important for all personnel involved in the management of SuDS or their construction, to understand how they work, and the parameters to which they have been designed. This will enable them to make informed decisions around requests for variations, confirmation of materials supply, and when 'hold points' are needed to enable the agreed inspections to be undertaken and recorded. It will also help those involved to understand tolerances and standards, particularly construction levels and slopes that are essential in making the scheme work as planned.

3.2 BASELINE INFORMATION NEEDED BEFORE CONSTRUCTION

Before works start, staff working on the site, ie both implementing and managing the works, need to have a full understanding of the site in its pre-development condition, what needs to be constructed and how it will be built. This will ensure that those managing or carrying out the works understand what is expected and the constraints they will have to work within.

The site

Information required about the site includes:

- Full topographic survey of the existing site, with contours to record levels at 500 mm intervals as a minimum for large/greenfield sites (for small/urban/very flat sites, closer level differences may be required) and spot levels for on-site surface features and changes of level.
- Details of all above and below ground services, with invert levels of all manholes, and detailed services information from statutory and utility providers (including on site surveys if necessary).
- Trees/vegetation/protected species or any historic or archaeological features to be protected on site, and the location/extent of protection required.
- Depth and size of existing surface water pipework/sewers and current/historic information regarding drains, ditches or watercourses into which the SuDS will be connected, including whether they are subject to flooding.
- Awareness of the potential impact of water flowing into the site from higher adjacent land (mainly on greenfield sites).
- The site investigation report including full infiltration tests, with trial holes in areas where infiltration is planned (see **The SuDS Manual (CIRIA C753) Section 25.3** for details on infiltration testing methods).
- Contact details for local stakeholders and any commitments made during the SuDS design stage for further involvement during construction.

- Information on previous land use that could affect the work, including contamination of the site or groundwater levels.

This information should be readily available from the client as it would have been required either for a planning application or to enable a detailed design to be undertaken for tender/construction purposes.



Handy hint

Undertake a visual survey (including photographs or videos) of the site to ensure that what is shown on the topographic survey appears the same as seen on the ground, as there may have been site activity between the time of the survey and when work starts.



Watch point

Be aware that service plans from the utility companies are rarely accurate. Service locations will need to be confirmed on site before excavations (this should have been undertaken as part of the detailed design process).

SuDS design

Information required by the builder/contractor about SuDS design includes:

- If SuDS are planned to infiltrate water into the ground and/or store water, and if they are to be lined.
- The management train showing all the SuDS components and how they link together from initial interception through to the discharge point from site.
- Location of the final discharge points (and connection point into the sewer if required).
- Existing and proposed levels that demonstrate the relationship between inlet and outflow levels at all points in the scheme from beginning to end, and the storage volumes required for each component.
- The permitted discharge rates from the site at each outfall.
- How ‘exceedance flows’ work (when the volume of rainfall is greater than the system’s drainage capacity) and how these link with the SuDS.
- Proposed contour plans/levels to confirm bank gradients for swales/ponds.
- Plans, sections and details sufficient to construct the scheme.
- Full specification for all products and materials required.
- Manufacturers’ recommended installation requirements for all proprietary products.

Before work starts, missing information that has been identified during pre-construction checking procedures, should be requested from the engineer/designer of the scheme, or from the client.



Hold point

Starting work without all the necessary information creates risk for the project’s successful delivery.

3.3 USING AND MANAGING SUDS DURING CONSTRUCTION

A key challenge in SuDS construction is the protection and maintenance of partially or fully completed components from over-compaction, damage, silt, sediments or pollution while the rest of the site is under construction.

Some sections of the SuDS scheme can be designed for use during the construction process, providing this is planned for (such as using the base course of permeable paving for access before laying the permeable surface layers). However, this can only be done if the necessary temporary construction measures are put in place. These should then be removed and/or remediated to allow the completed component to function as planned (see **Part D Chapter 12** for information on using SuDS for site access). Swales may also be excavated and used temporarily for site runoff, but should also be fully remediated before final construction and planting. On redevelopment sites the existing site drainage is likely to be disconnected, which will require other temporary arrangements to be put in place to drain the site during construction.

3.4 MAINTAINING COMPLETED SUDS UNTIL HANDOVER

The actions required to protect and maintain finished phases of the works are discussed in **Part D Chapter 13**, but it is important to be aware of and plan for these temporary requirements from the beginning. If the finished SuDS cannot be protected it may not be realistic to complete some sections early in the construction process.



Watch point

When constructing SuDS it is essential that all existing buried services are physically located and marked on site before excavation takes place. Once accurately located, check against the proposed design, and inform the original designer if the location of existing services affects the design's construction.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Exceedance flow** is the overflow of water from a drainage system that occurs when the rainfall is greater than the capacity of the system.
- **Infiltration** is where water is allowed to soak into the ground.
- **Interception** is preventing runoff from leaving a site for the majority of small rainfall events.
- A **management train** is a sequence of components that are connected together to drain surface water from a site.
- A **swale** is a SuDS component that is similar to a wide shallow ditch, but with a flat bottom.



4 UNDERSTANDING THE DESIGN REQUIREMENTS

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Chapter 4

Understanding the design requirements

This chapter provides information on ensuring that the design requirements for SuDS are fully understood before construction.

► *A pre-construction checklist is provided in Part B Section 6.1.*

4.1 INTRODUCTION

SuDS construction is generally simple civil engineering groundworks, involving cut and fill, re-grading, spreading of soils, and the installation of inlets or outlets, pipes and chambers. However, other aspects need more specialist knowledge, such as the installation of proprietary systems or the use of less familiar techniques, such as skeleton (large stone/ rock based) soils on site for trees within hard paving. Those managing the installation should understand how each SuDS component works, what needs to be built and any programming constraints, to ensure it performs as designed on completion (see **Part G Case study 37.1**). Ideally the SuDS designers should be involved with the construction process, and available to share their knowledge with the site team.

4.2 UNDERSTANDING THE DESIGN

What the design drawings need to show

The SuDS design drawings should be accompanied by a SuDS design report that explains in simple terms what the design is to achieve and how the system will work. It should include a design diagram that shows the flow routes through the system and storage areas for runoff.

The purpose of the SuDS design report is to summarise the critical design factors and assumptions that have determined the design. This does not have to be a long-winded report, but it should communicate clear messages to those building the SuDS. The most effective form of communication is a short one- or two-page summary of the information, along with a clear design diagram. Any communication of relevant unusual risk that is required under the Construction (Design and Management) Regulations 2015 (CDM 2015) should also be included in the report. It is different to a SuDS design philosophy statement that is submitted as part of the planning or other approval process.

Check that the design drawings and specification clearly define:

- what each SuDS component is, how they connect, and what those connections are
- how levels through the system are consistent from inlet to outfall
- how runoff flows through the SuDS and moves between different components
- whether the SuDS discharges water into the ground (infiltration), or the location of the final outfall to a watercourse, or the location of the final connection to an existing sewer
- how cut and fill is to be achieved across the site, and the levels of each component as part of the re-grading, including levels at inlets and outlets, and the grading of banks and slopes or hard surfaces adjacent to each component

- that balancing cut and fill has been considered, and whether soil is to be imported, disposed offsite or reused elsewhere within the scheme
- whether the components are constructed from existing natural, engineered or specialist soils
- whether components are lined and what lining materials are to be used
- which areas (if any) are expected to infiltrate water, and require protection during construction
- how specialist/proprietary SuDS components are to be installed
- physical appearance/finishes of visible hard components
- full specification of planting and seeding, including the species, quantities, and their size/spread/spacing.

What the specification needs to include

Check that the specification provides:

- details about the materials used and any specialist suppliers
- the standards (British, European etc) that must be complied with and any specialist requirements
- what needs checking, when, and by whom
- what needs sampling and/or testing, when, and by whom
- what needs to be recorded (both written and photographically) as part of the build process, particularly items that will be covered up.

Missing information should be requested from the SuDS designer or from the client, before construction works begin. It should also be clear who approves design/specification changes, and their potential impact on the performance of the system, before instructions and/or variations are confirmed. No materials or products should be changed without the agreement of the SuDS designer.



Handy hint

Ensure that the inspection requirements of the supervising designer or adopting body are fully included in the site management planning process.

Identify all inspections within the site management planning process for each phase, and review/adjust as necessary as the project progresses.



Watch point

'The way I've always done it' may not be appropriate for SuDS.

Large water storage volumes held above natural ground level may require the appointment of a reservoir/panel engineer (threshold 10 000 m^3 for registration, but subject to risk assessment). Seek advice from the designer if in doubt. See also Reservoirs Act 1975 as amended by the Flood and Water Management Act 2010.



Hold point

Changes that potentially affect the aesthetics, capacity or performance of the system should be evaluated and approved by the SuDS designer.

Works should be inspected and approved before being covered up. Multiple layers may require multiple inspections.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Infiltration** is where water is allowed to soak into the ground.
- **Skeleton soils** are made up of large pieces of rock or aggregate with finer soil washed into the voids between pieces of rock. They are used to provide a suitable medium for healthy tree roots.
- The **SuDS design report** is a summary of the key technical issues that need to be understood by the construction team.
- **The Construction (Design and Management) Regulations 2015 (CDM 2015)** apply to construction work in England, Scotland and Wales. CDM 2015 set out the duties in respect of the planning, management and monitoring of health, safety and welfare within the design and construction process and the management of a facility, and of the co-ordination of performing these duties by duty holders. Duties applicable to all projects are those of the client, designer and contractor. Where more than one contractor is working on site the additional duties of principal designer and principal contractor also apply.



5 SITE CONSIDERATIONS

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Chapter 5

Site considerations

This chapter provides information on what to consider on site at the pre-construction stage.

- *General good practice guidance on the construction of SuDS schemes can be found in The SuDS Manual (CIRIA C753).*

5.1 INTRODUCTION

General construction works will always need to consider a wide range of site issues to enable a scheme to be built, however some of these issues should be considered specifically in relation to SuDS (see **Part G Case study 37.3**).

5.2 SITE CONSIDERATIONS ON- AND OFF-SITE

Tables 5.1 and 5.2 provide typical lists of potential issues, but may not be comprehensive for all sites.

TABLE 5.1 Measures to address off-site issues

Be aware of	What can go wrong	Consider
Existing water systems or watercourses near to the site.	Water could overflow onto the site during extreme rainfall and/or wash muddy water into SuDS components.	Using protective measures around the uphill side of SuDS components where close to a boundary/water source.
Potential overland flows from agricultural land.		
How construction site runoff is managed during the works.	May pollute watercourse/ habitats downstream.	Using SuDS as temporary storage components, but they should be fully remediated at the end.
Boundary and off-site trees – overhanging branches and root systems.	May reduce the use of large excavation equipment for SuDS.	Agreeing a method statement for acceptable working distances and methods of excavation.

TABLE 5.2 Measures to address on-site issues

Be aware of	What can go wrong	Consider
Need for consents	Consent may be needed to work in particular areas, for example close to watercourses. If it is not obtained it can lead to delays and/or prosecution (and associated bad publicity).	Reviewing the need for consent before starting on site.
Groundwater level changes	High water table may not have been picked up due to seasonal variations.	Monitoring and seeking advice from the designer if the problem arises.
Existing areas of damp ground/vegetation	If left unmanaged, protected species may colonise, and then require formal consent to be removed or relocated.	Checking that there is a current ecological assessment (less than a year) and consult a registered ecologist for guidance on appropriate management.
Existing underground services	Exact locations may not be known until excavations start or additional services may be found. This may have implications for the layout and performance of the system if design changes are required.	Ensuring all utility information is obtained in advance. Undertake detailed utility survey where necessary. If variation is required, due to utility locations, contact original designer to ensure system maintains designed capacity, quality improvements and visual quality. Hand excavation around all services.
Proposed underground services clashing with proposed location of SuDS	Services installed without considering implications for SuDS levels and location.	Ensuring all services are co-ordinated before work starts, and subcontractors are aware that agreed service runs and their depths should not be changed without agreement.
Contaminated material	Pollutants/contamination may be encountered during excavations.	Depending on whether capping or removal is the preferred option, contact the original designer to ensure system maintains designed capacity and does not mobilise pollutants.
Areas designed for infiltration	If not protected before construction starting, they may become compacted and their ability to infiltrate damaged.	Checking design drawings for infiltration areas, and provide the required protection measures.
Trees or planting to be retained and protected (including off-site trees)	Extent of area to be protected may not have been fully considered at design stage to allow space for SuDS to be constructed.	Checking protection drawings, and take advice from appropriate professional (eg arborist/ landscape architect). Ensure design changes maintain the design system capacity. Ensure off-site trees are included in the survey (if off-site access is not possible, then make an informed assessment).
Maintenance requirements for existing vegetation	Leaf litter can affect/block outlets.	Ensuring an appropriate and regular maintenance regime is in place during construction.
Habitats or species to be retained and protected	Works may be subject to seasonal restrictions, affecting the timing of the works or equipment to be used.	Works may need a license from Natural England[1]. Take advice from appropriate professional (eg ecologist) to ensure compliance.
SuDS (generally) should not be directly connected to existing ponds, wetlands or areas of ecological importance without permission	Design changes/variations may be proposed as direct connection may be considered an easier/simple option.	Take advice from an appropriate professional (eg ecologist) and/or consult the local authority.
Requirement to retain public access through site	Health and safety risks where there are unfinished SuDS ponds or other water features, if not managed in accordance with good practice.	Public access may affect the programme of works. Comprehensive use of barriers and signs, and strategy for its maintenance and management throughout the contract, aligned to the work programme and risk assessment according to CDM 2015.

Note

1 Natural Resources Wales, Scottish National Heritage or the Northern Ireland Environment Agency in the devolved administrations.

CASE STUDY 5.1

Impact of buried services or unexpected obstructions



Figure 5.1 Grass reinforced concrete units used on top of service lines provide suitable protection



Figure 5.2 Existing asphalt surfaces being broken up



Figure 5.3 Fully-lined SuDS cell used where infiltration could cause migration of contamination. Also note visible existing services running beneath geomembrane

A major city council had planned the narrowing of a dual carriage ring road to single carriageway. This allowed an extensive series of bioretention systems to be retrofitted within the densely-developed city centre. Sufficient time was allocated for pre-construction site investigations to avoid potential disruption or unanticipated issues arising on site. The budget also included a contingency to cover unforeseen (below ground) works, and time to undertake the necessary community consultation.

Due to the location of the scheme, working around existing services was a major consideration and had informed the design. Three major 270v electricity cables, supplying a third of the city, run through the site. A close working relationship was developed with the service providers from the start. Extensive trial holes were excavated on site to ensure accurate plotting of services and allow the design to be adapted as necessary before construction. In one incident, a major electricity cable was encountered during construction at a much higher ground level than anticipated. This meant the design had to be amended to incorporate concrete grass reinforcement and additional waterproofing to meet the service provider's requirements to protect the services from accidental or water damage.

With the site's location having a strong industrial history, soil contamination was of high concern – its disturbance could potentially cause extensive pollution of nearby watercourses. The design included geomembrane liners, which had to be carefully detailed around and over the buried services.

Despite all the pre-planning work, a major unanticipated problem was encountered during excavations when historic tram tracks were discovered. This required extensive works to remove them to enable the planned bioretention systems to be constructed. As an unexpected issue, this caused further delays to the schedule of works, which could have been avoided had they been found earlier in the design process.

Lessons learnt

- Investment in pre-construction phase investigations for both redevelopment and retrofitted sites can reduce the risk of unexpected ground conditions or obstructions, limiting unexpected costs and delays during construction phases.



Figure 5.4 Existing underground services can create difficult on-site issues

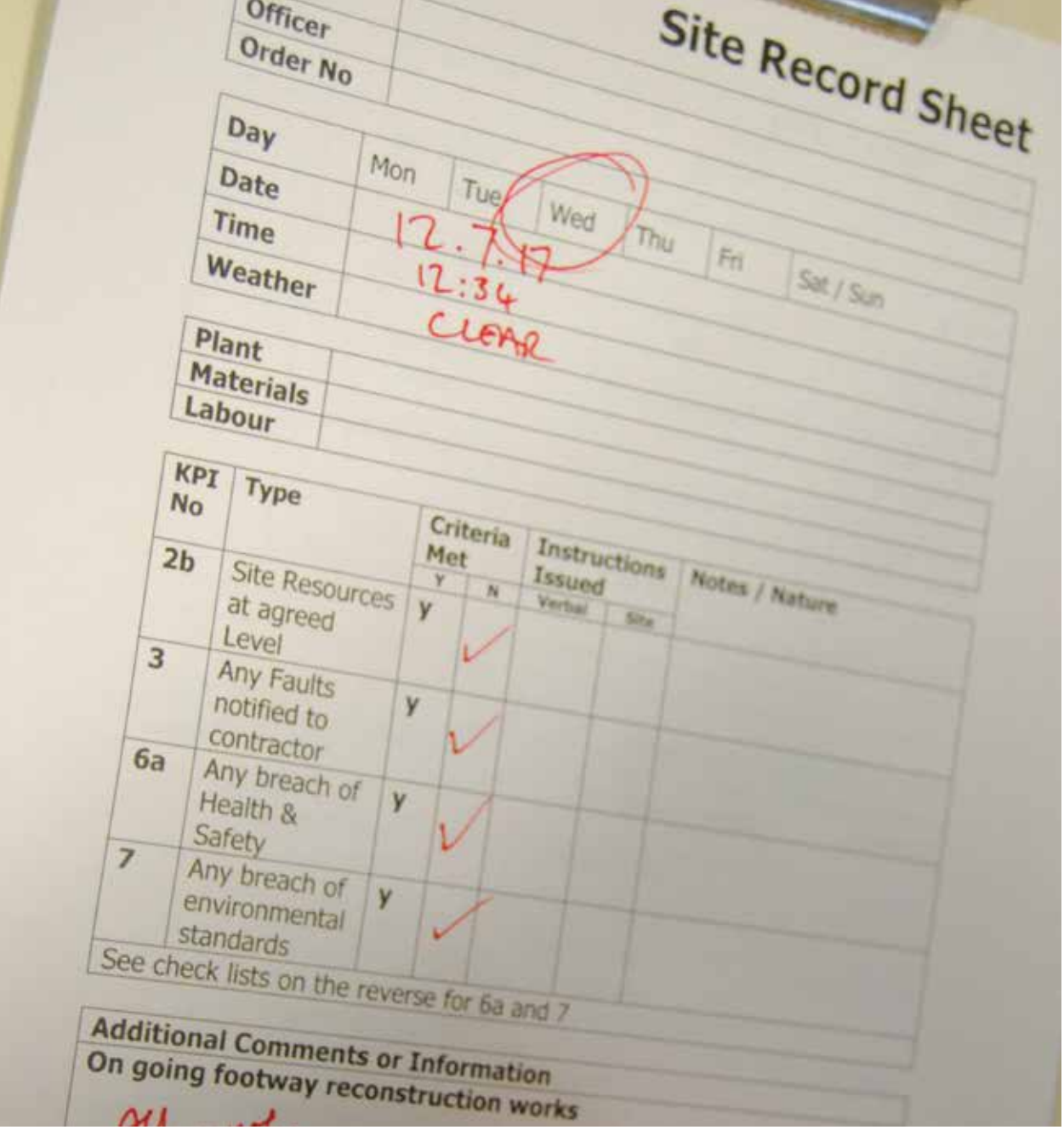


Handy hint

Where a site has existing damp areas the land/vegetation should be managed before development to ensure that protected species do not colonise it. Seek advice from an ecologist for an appropriate management regime.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Infiltration** is where water is allowed to soak into the ground.
- **Concrete grass reinforcement**. Concrete paving blocks with holes to allow grass to grow. Commonly referred to as 'grasscrete' although this is a protected trade name for one supplier.



6 PRE-CONSTRUCTION CHECKLIST

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Chapter 6

Pre-construction checklist

This chapter provides a checklist of items to consider at the pre-construction stage.

- *A management planning checklist is provided in Part C Chapter 10.*
- *General construction checklists are provided in Appendix A1.*
- *General guidance on Construction Method Statements can be found in The SuDS Manual (CIRIA C753).*

6.1 INTRODUCTION

Ensuring that the right information is available to the site team about the design of the project and the actual site are important parts of the pre-construction stage.

The following list is intended to highlight typical considerations, but should be supplemented by others that are relevant for each specific SuDS construction site.

6.2 PRE-CONSTRUCTION CHECKLIST

The Construcion Method Statement (CMS) and site health and safety assessment should also include issues that may be specifically relevant to SuDS.

This information should be obtained before works begin. Where design information is not available, the SuDS designer should be consulted. The checking and verification programme may require ongoing discussion and amendment as the works progress to reflect the actual (versus planned) site programme, and unexpected site circumstances, such as unmapped services, site contamination etc.

The pre-construction stage also covers site construction planning and phasing of the project (see **Part C**).

6.3 CONSTRUCTION METHOD STATEMENTS

A CMS is a useful way to combine the key issues that need to be addressed for a site and its constraints, the construction requirements of the scheme, the inter-relationship with all other site works, and any phasing requirements (see **Part C**).

CMS are widely used throughout the industry, with a major emphasis on addressing health and safety issues, however, they are even more useful where they are broadened to encompass delivery of the overall project. Their value for SuDS construction is in raising awareness of the constraints and requirements on site works, that can otherwise damage completed works, or make construction more costly or difficult.

Typically, a SuDS CMS should identify:

- who is responsible for completing the works
- phasing of the SuDS as a whole and their integration with the overall site construction plan
- the works that can be completed early and effectively protected (and how)
- constraints on general site works and co-ordination of other activities with the SuDS
- any particular working requirements.



Watch point

As part of the CDM 2015 risk assessment unusual hazards or risks that will be present during construction should be identified on design drawings. SuDS-specific hazards may include working near water.

TABLE 6.1 Pre-construction checklist	✓
Is there sufficiently detailed topographic information available about the site?	
Have all below ground services been surveyed, and is all statutory and utility provider information available?	
Are full details available of the extent or protection zones and approved protection measure for trees and habitats to be retained, or constraints around heritage artefacts or structures? Is information available regarding the restrictions of seasonal works for protected species?	
Is all information available regarding watercourses, drainage ditches or culverts, and history of flooding?	
Has the potential impact of water flow from off-site land been considered?	
Is the full site investigation report available? Does it include infiltration tests for areas designed for infiltration?	
Are any studies into the previous use of the land available (such as contamination or groundwater)?	
Are the construction drawings and specifications for all the SuDS available? Do they include full planting plans and specification? Make sure the drawings are the latest versions issued for construction and provide adequate information to allow construction.	
Do the construction drawings clearly show the management train, and whether the SuDS is an infiltration or attenuation system? Is the SuDS design report available?	
Are all levels at inlets and outlets provided along with storage volumes for each component and the permitted discharge rate from site? Are the levels in the system consistent with the level of the discharge point? Check the level of the discharge point before starting construction.	
Is the management of exceedance flows shown on the design drawings? Do they show how they interact with the main SuDS component or scheme?	
Are full contour plans (which include levels) for all ground works, banks, basins and other components provided?	
Have the designers considered the overall cut and fill requirements for the site against proposed levels?	
Are the details of specialist suppliers available, along with the manufacturer's recommended installation requirements for all proprietary products?	
Have the installation standards for all construction items been confirmed?	
Has a schedule of construction inspection checklists and hold points been compiled and agreed?	
Has it been agreed who will inspect each part of the works for each/every phase, the notice required before inspection, and what needs to be recorded (written and photographically)?	
Is the local community aware of the SuDS scheme and do they understand the approach taken?	

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Exceedance flow** is the overflow of water from a drainage system that occurs when the rainfall is greater than the capacity of the system.
- **Infiltration** is where water is allowed to soak into the ground.
- A **management train** is a sequence of components that are connected together to drain surface water from a site.

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7 THE SITE TEAM

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Chapter 7

The site team

This chapter provides information on the site team responsible for the construction of SuDS.

7.1 THE SITE TEAM'S SUDS ROLE

The site team (including designer, contract manager, site manager, foreman and site supervisor) who are involved in constructing SuDS may be the same as the team used to construct traditional drainage systems. While roles may be similar, the site team's actions and skills will be different for SuDS construction. The successful construction of the system will depend on all involved understanding the different approaches and working accordingly (see **Table 7.1 and Part G Case study 37.1**).

TABLE 7.1 Roles within the SuDS construction team both pre-contract and during construction

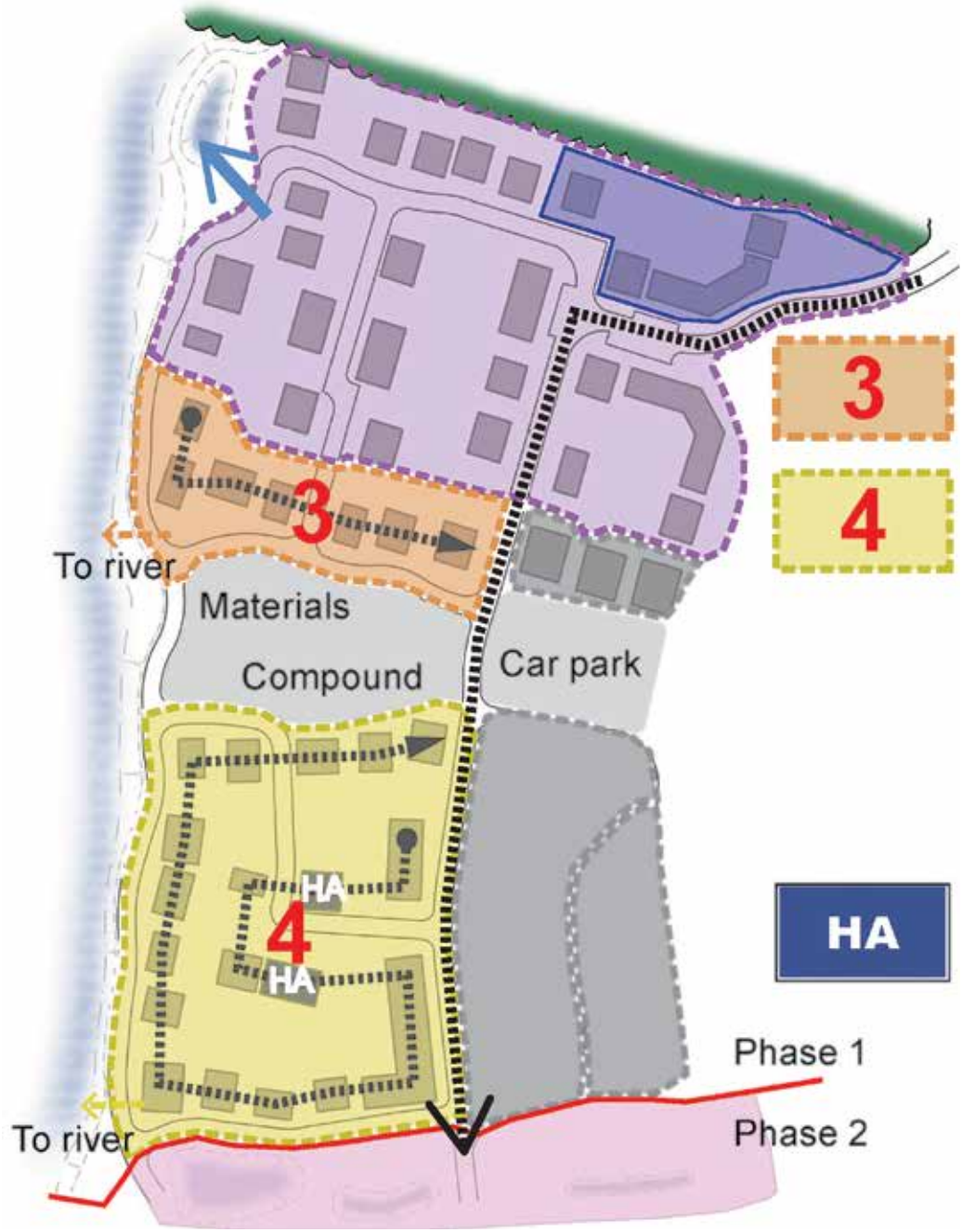
From design through to construction		During construction							
Site designer		*Contract manager*		*Site manager*		*Foreman/site supervisor*		*Site operatives*	
Their input to traditional drainage construction	**What will they do differently for construction of SuDS?**	**Their input to traditional drainage construction**	**What will they do differently for construction of SuDS?**	**Their input to traditional drainage construction**	**What will they do differently for construction of SuDS?**	**Their input to traditional drainage construction**	**What will they do differently for construction of SuDS?**	**Their input to traditional drainage construction**	**What will they do differently for construction of SuDS?**
Employed after site layout is determined, but little input into it	Should be involved throughout the design development process to influence the site layout and enable SuDS to be incorporated effectively, and delivered as planned. SuDS should be designed for ease of construction.	Manage a single subcontract package for groundworks and road/sewer construction.	Manage several different packages that would normally fall outside drainage construction, from landscape to ground modelling.	Supervise a single subcontract package for groundworks and road/sewer construction.	Supervise and co-ordinate works for different subcontractors who may work only work on a single SuDS component or on different phases of construction.	Manages/ supervises the day to day construction including trench excavation, pipe laying and backfilling, and manhole construction.	Day to day supervision of wide range of installations where levels, tolerances and details are the key to success, some of which may be unfamiliar.	Trench excavation, including pipe laying, backfilling, manhole construction etc	Requires a wide range of expertise from different operatives, from trench excavation and pipe laying, to paving construction, re-grading and planting
Drainage engineers model, design and specify the surface water system	Drainage design team will include a range of professionals, eg drainage engineers, architects, public health engineers, landscape professionals, ecologists, planners, sports pitch designers etc.	Surface water sewer construction is programmed as one of the first elements to be constructed.	Construction of the surface water management scheme (or parts of the scheme) is programmed to occur at various times throughout the construction process.	Manage construction of the surface water drainage as one of first items and use the system to drain the site during construction. Use sub-base as construction access/ platform.	Manage SuDS construction taking place throughout the development/ construction. Some SuDS may be located on roofs of buildings rather than at ground level. It may not be possible to use the road sub-base as a construction platform (if it is permeable).	Work to tolerances for drainage and designs – an area where they have a lot of experience.	Ensure that where tolerances are tighter for SuDS construction, that they are achieved.	Landscape contractor or subcontractor are not involved with drainage.	Landscape contractors working on a SuDS need to understand the requirements that may be different to traditional landscape practice (eg tighter tolerances may be necessary).
Scheme designed to adoption standards of sewerage undertaker, highways or local authority (LA)	Scheme designed to adoption standards of adopting body (which may be a wider range of organisations). Design to meet guidance in The SuDS Manual (CIRIA C753) is a common requirement.	Check construction drawings and design intent to ensure all material is in place to successfully construct the scheme.	Check construction drawings and design intent to ensure all material is in place to successfully construct the scheme. Required to check a wider/more complex range of materials.	Will need to consider the impact of construction activities on piped drainage system.	Consider impact of construction activities on SuDS or partially completed SuDS (eg muddy runoff running into swales, or cranes needing to access on top of plastic tanks). Programme temporary drainage measures where appropriate.	Required to work with a wider/more complex range of materials.	Ensure the site team are trained to build using unfamiliar materials or processes.	Limited input	Planting to soft SuDS, requires an understanding of the specialised soils needed for different components.
Limited input during construction as materials are well understood and changes have no impact on other aspects of development	Should be consulted when changes made to site levels, material specifications, etc are proposed, as some changes can have wider implications (eg on physical appearance or performance of landscape).			Ensure drainage runs do not conflict with tree planting – which can result in tree planting being changed on site.	Supervise and understand the requirements for soft SuDS planting to ensure it can be installed as per construction drawings/ specification.				

TABLE 7.2 The client, their representative and the SuDS adopting body's role

Adopting body or client's representative		Client	
Their input to traditional drainage construction	***What will they do differently for construction of SuDS?***	***Their input to traditional drainage construction***	***What will they do differently for construction of SuDS?***
Traditionally adopted by sewerage undertakers/ highways and local authorities	May be adopted by a range of organisations including sewerage undertakers, local authorities, private companies or voluntary bodies/local trusts	Little input to construction as it does not affect visual appearance of the site	Need to be aware of the visual implications of surface SuDS on the appearance of development and the ongoing grounds maintenance for landscape elements of the project to maintain visual quality as well as drainage function
Inspection of construction at defined points during construction – pipes and manholes Limited range of input required	Inspection of SuDS at suitable stages during construction programme – pipes and manholes, plus a wide range of other components including pervious surface and landscape based SuDS. Wider range of input/ expertise required which will include understanding of landscape construction issues during construction	Will require confirmation that completed drainage functions properly – simple approach by inspections during construction and pressure testing pipes and pre-handover CCTV survey etc	Some SuDS components are difficult to test and inspect once completed. Client requires confirmation that the completed SuDS meet all the requirements of the design and are constructed as per design – this will require more supervision on site than traditional drainage. As-built surveys are likely to be required to confirm design compliance
Where the drainage is to be adopted, the approving and adopting body are the same	The approving and adopting bodies may be different, with potential differences of opinion over standards/ approvals		
A single body adopts all surface water system not in the highway (within the rules for what it has to adopt) subject to acceptable construction	Maintenance arrangements should be made clear before construction starts. Different parts of the system may be adopted by different organisations – these interfaces need to be managed, and clarity provided over responsibility – multiple organisations may be inspecting and maintaining the SuDS, and their physical relationships could be complex		

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- A **swale** is a SuDS component that is similar to a wide shallow ditch, but with a flat bottom.
- **Traditional drainage** is designed to remove water quickly from a site using pipes. Rainwater is seen as a challenge to remove and there is no consideration of using the rainwater or the drainage system to provide additional benefits such as biodiversity or improving the landscape.



8 FACTORS INFLUENCING PHASING OF SUDS CONSTRUCTION WORKS

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Chapter 8

Factors influencing phasing of SuDS construction works

This chapter provides information on the factors influencing phasing of works on site.

► *Detailed information on how to scope and develop construction programmes can be found in The SuDS Manual (CIRIA C753) Section 31.2.*

8.1 TYPICAL FACTORS

The factors influencing the phasing of a SuDS construction project vary, depending on:

- what is being built
- scale of the project
- location of site and runoff discharge points
- access arrangements (existing and proposed)
- compliance with the requirements of planning conditions and environmental legislation
- timescale for construction
- time of year construction starts (ie seasons affect earthworks and planting)
- fixed completion dates
- the need to relocate users/residents from site
- funding
- statutory constraints, such as licensing consent for protected species
- project partners and client requirements, eg for early handover of parts of a development (and early completion of phased development)
- the economic environment
- snagging requirements and the length of the maintenance period.

These issues will influence the overall phasing of the construction programme.

8.2 WHY IS PHASING IMPORTANT?

The challenge for SuDS construction

The preceding factors will directly influence the building works, which usually follows a standard sequence of:

1 Site set up.
2 Start on site.
3 Major civil engineering works and below ground services.
4 Building/structure construction.
5 Finishing civil works.
6 Landscape works.
7 Handover
8 Reinstatement of off-site works.

When and how the SuDS are built can be difficult to integrate within the usual programme, because they need to be completed and maintained in good condition, while the rest of the site works are being built (see **Part G Case studies 37.2 and 37.3**). The key exception to this is pervious paving, where permeable sub-bases can be temporarily covered with asphalt then at the end the asphalt is cored out and the pervious surface overlaid on it (see **Part D Chapter 12**).

General construction factors to consider versus specific SuDS requirements

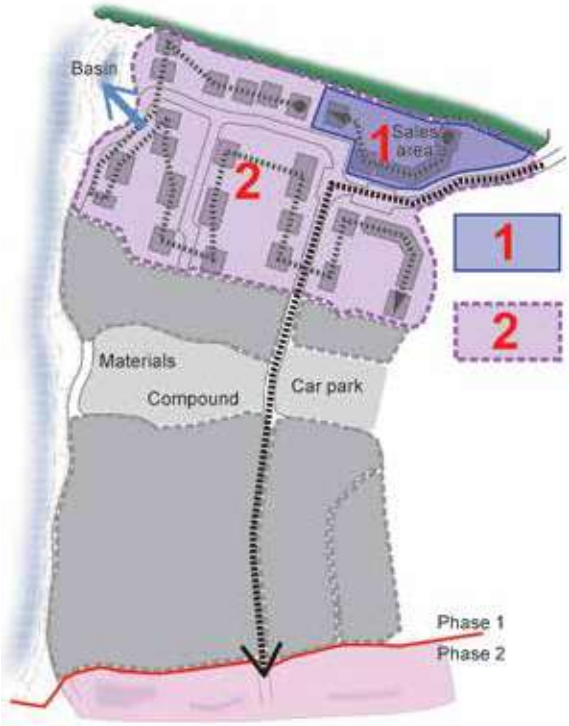
The client may influence completion of works, where they require early completion or access to some parts of the site, or specific buildings within it. This requires the external works in those locations to be completed outside a logical construction sequence and often occurs in relation to housing, where completion of 'show homes' at the front entrance will be a key requirement. Houses should be delivered in a sequence along selected streets and in a way that may not relate to how the SuDS can practically be connected to its discharge point. A temporary drainage solution may be required until the appropriate connections are put in place. Housing associations may want the street scene to be fully completed before they accept houses for occupation. This will influence whether permeable paving is a suitable surface as it may be at risk of surface clogging while the rest of the development is constructed.

Typical example for a housing site

Figure 8.1 illustrates how the SuDS scheme has been implemented in stages, but with the earliest phases unable to make their off-site connections at the time of the initial construction. Priority is given to building the show homes at the front entrance, rather than a 'SuDS logical' approach, which would start at the lowest level downstream section, work upstream and out of the site. Similarly, spatial constraints mean that the location of the two major SuDS ponds were used during construction for site parking and storage of materials, so the ponds could only be built in the final stages of the project delivery programme. Where sequencing is not ideal for SuDS, the land should be restored to a suitable condition before the SuDS construction (such as de-compacting soils, and removing site pollution/sediments).

TABLE 8.1 Construction phasing challenges for SuDS

Construction factors that affect phasing	Potential challenge for SuDS
Need for construction access	Can areas of pervious paving be used, if protected? Design should allow for the weight and amount of construction phase traffic. Are there limitations to the weight of construction plant allowed to run over attenuation tanks that have been installed?
Storage of topsoil and other materials	Open space areas are often used for compounds and material storage. SuDS areas may conflict with space needed for storage of soil or other materials. Stockpiles can influence movement of surface water across a site.
Major cut and fill undertaken early in the contract	If completed early, can the SuDS be maintained in good condition? Is there sufficient space on site to allow SuDS to be completed early?
Site drainage	Some SuDS may be used temporarily for site drainage, but will require full restoration before completion. Site drainage should not discharge into completed SuDS unless approved by the designer. Temporary outfalls may be required before full completion of the SuDS.
Procurement of planting	May need to pre-order plants to secure supply in-line with programme due to seasonal availability.
Procurement of materials and products	May need to pre-order materials or products that have lead-in times. The availability of aggregates, porous concrete or asphalt will depend on proximity to quarries and batching plants.
SuDS construction to be phased, but taking consideration of remediation works to deal with contamination	Excavation for SuDS should not take place after capping layer construction (or capping layer should be replaced as necessary below the SuDS).



Sales area and show home completed first

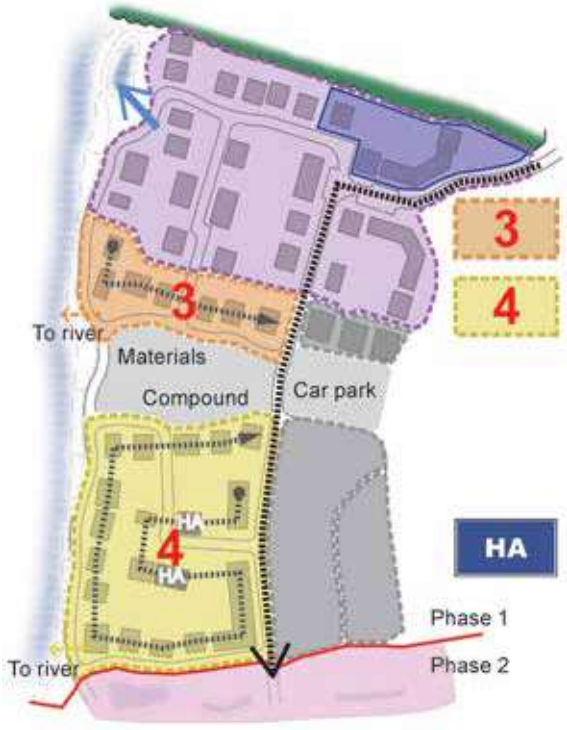
First group of units – Areas 1 and 2

Drained by piped system to basin with geocellular units below it to increase capacity within limited areas.

Basin installed during first operation on site with drainage and road infrastructure.

Considerations:

- basin needs to be used for construction runoff – needs silt management.



Areas 3 and 4

- These will drain to basin and swales in public open space (POS) at completion.
- During construction and before SuDS construction, water will temporarily discharge to watercourse.

Considerations:

- suitable route for temporary discharge
- connecting drainage to a temporary, and then a final, discharge point
- pollution control during construction.

Units for housing

- Housing associations normally require a completed street scape before they will take possession of any units. This includes any concrete block paving to ensure the safety of residents.
- Concrete block permeable paving may not be suitable in these areas if it has to be laid before the completion of other areas.
- The main construction route will have mud on it at times, which could get tracked into side roads and clog the permeable surface.
- Basins and swales will also have to be completed in the POS before occupation.

Figure 8.1 Site planning diagrams



Areas 5 and 6

- Drains to swales and basin in POS.
- Temporary connection not practical for this area.
- Cannot be completed until site facilities are relocated and SuDS in POS constructed.

- Remediation taking place in Phase 2 area not available for compound or materials storage during construction of phases.
- Not available for SUDS construction until after completion of units in Phase 4, 5 and 7 – temporary discharge required.

Figure 8.1 Site planning diagrams (contd)

Key

Main construction access

Should be solid surfacing during construction. If a permeable finish is required, this is to be laid post-construction (see **Part E, Chapter 24**).

Build sequence and direction of build in each area

- To be based on the sales plan for the site, which determines the number and type of units to be built each year.

Swales and basins within POS

- Areas required for site offices, compound, materials storage and parking for site staff.
- Not available for SuDS construction until Phase 2 is released by the remediation contractor and site facilities can be relocated.

Temporary discharge until final SuDS is constructed

Direction of surface flow to SuDS features

Considerations:

- presentation of the public frontages for sales
- infrastructure in place to allow the planned number of units to be completed
- cranes used throughout the site for lifting roof trusses etc into place
- crane movement over geocellular tanks and permeable sub-base required – especially in areas not designed for HGV traffic in the final layout
- stability over geocellular tanks and permeable sub-base required during lifting operations (see **Part D, Chapter 12**)
- SuDS are required to fit around these issues.



Handy hint

Ordering plants early in the contract will ensure that the correct species are supplied in the correct sizes, and are available when required. Trees may also be containerised for availability outside the normal planting season. These can be ordered direct from a wholesale nursery or through the landscape contractor.



9 GETTING THE RIGHT MATERIALS FOR THE JOB

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Chapter 9

Getting the right materials for the job

This chapter provides information on the decisions to be taken when ordering materials for the project.

9.1 INTRODUCTION

The specification should determine what materials are ordered for a site. However, collective purchase agreements, long lead-in times for specialist items and offers of alternatives that appear similar can result in materials being purchased that are not suited to the purpose of the scheme. This could significantly affect its performance.

So, when planning construction, it is important to understand:

- lead-in times
- reasons why specialist items have been selected and their particular qualities if there is a desire to change supplier
- acceptability of alternative products.

9.2 QUESTIONS TO ASK

As with potential variations, changes or substitutions of the materials specified will need to be checked and confirmed by the original SuDS designer or novated/ contractor, or employed designer. This person should have a full understanding of the SuDS components and their planned performance in the overall system. Some substitutions could offer additional benefits or better performance, so should not automatically be discounted.

TABLE 9.1 Factors to be considered where variations to the works or substitute products are proposed

Getting the right materials	What needs checking?
Understanding the lead-in times for all specified materials	Timescales from ordering to delivery to ensure that the need for substitutions can be avoided.
Understanding the properties of specialist items if substitutions are being considered	Whether the substitute offers the same qualities/performance as what was specified. If the substitute offers the same service life. Whether the original or substitute product require specialist installers or repair procedures. If the manufacturer's guarantees are similar. Any different maintenance obligations.
Aggregates and soils	The particle mixes and properties are the same. The same performance (ie strength, durability, permeability or filtration performance, porosity)
Plants	That the species are suitable for the location. Changes to the plant's specification are acceptable, eg overall size and stem-girth (for trees), or whether root-balled or container grown Robustness of smaller sizes may be affected within the planned location
Seed mixes	Whether a change to the seed mix affects the requirements for native provenance or for a specific species mix suited to the SuDS



Watch point

Changes from specified products should not allow the capacity of the SuDS, its performance or safety to be undermined.

Check whether changes of material will negatively affect the SuDS robustness, performance or maintenance requirements with the SuDS designer.

CASE STUDY 9.1

Influence of procurement route for materials when changes to programme occur



Figure 9.1 Moving attenuation tank units into prepared excavation area

On a large-scale attenuation tank installation, many site constraints were considered such as foundations of neighbouring buildings, excavation support, plant height restrictions and access, and the specific backfill sequence to ensure a safe weight loading of the tanks.

'Just in time' delivery was arranged to match a staggered installation programme due to restricted storage space on site. However the complex schedule of works was disrupted by a three day delay in the delivery of the attenuation tank units due to import customs inspections.

Materials had been procured separately from the subcontractors installing them, so the main contractor was responsible for storage of the delivery at the last minute. If the units had been procured via the subcontractor, their warehouse storage facilities could have been used.

Lessons learnt

- Where specialist materials are procured separately from subcontracted installers this can add complexity to programming, and increase responsibility of the main contractor. The situation would have been dealt with better as a complete package to simplify this already complex project.

Jargon buster

- A **novated designer** is where an original member of the design team that was directly employed by the client, has their employment transferred to the contractor when the successful company is appointed.



10 SITE MANAGEMENT PLANNING CHECKLIST

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Chapter 10

Site management planning checklist

This chapter provides a checklist of items to consider at the construction planning stage.

- *A construction checklist for final handover is provided in Part E Section 18.2.*
- *General good practice guidance on the constructions of SuDS schemes can be found in The SuDS Manual (CIRIA C753).*

10.1 INTRODUCTION

Anticipating how the site operations need to be managed throughout the construction programme can help avoid many typical challenges. **Part B** considered the information required about the site, its design and the physical constraints, while **Table 10.1** is intended to highlight typical construction management issues. These should be supplemented by any other factors relevant to each particular SuDS construction site.

The issues noted here will require ongoing consideration and review throughout the construction process as the site works progress.

TABLE 10.1 Factors that influence SuDS

What areas will be used for construction access, cranes etc?
Are permeable paving or attenuation tanks planned below this area?
Have loads and traffic limitations be checked with the designer? Ensure to design appropriate protection as necessary.
What areas will be used to store materials?
Is there a conflict with SuDS construction (ie whether location of SuDS will need to be used to store materials)?
What areas of cut and fill are required before SuDS can be completed?
Which area of SuDS will be completed early and/or need erosion protection?
Are any of the permanent SuDS to be used for construction drainage?
What planting is required and what are the lead-in times?
What soil/SuDS remediation works will be required (ie compare the programme with the SuDS construction to ensure there are no conflicts)?
Will temporary outlets for drainage be required before the SuDS can be completed?
What are the lead-in times for all SuDS materials including the sub-base for permeable surfaces, attenuation tank units etc?
How will the seasons or weather conditions affect the planting programme? Will the specification for plants (containerised/container grown instead of bare root) need to be reconsidered?
Will erosion control/re-turfing due to poor grass establishment during winter months be monitored?
When will the regulators or adopting body need to inspect the works and what advance notice do they require?
Who will advise them of the programme?

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11 MANAGING SOILS ON SITE

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Chapter 11

Managing soils on site

This chapter provides information to ensure that soils are maintained in good condition for reuse as part of SuDS.

► *A construction checklist for managing site soils is provided in Section 11.4.*

11.1 INTRODUCTION

Natural topsoil is a precious and expensive resource, so when it is stripped, suitable quantities should be retained and managed in good condition, for reuse on site where possible. Natural site topsoil is also the most appropriate constituent mix for that particular site, as it is biologically suited to the local underlying geology and the general environment. While some of the soils required for SuDS may be 'engineered' rather than natural soils, it is likely (depending on the scale of the SuDS) that the original site soil can be reused within the mix. At the same time, natural soils will be required for the banks and edges of the SuDS beyond areas of engineered soils.

11.2 KEEPING SOIL IN GOOD CONDITION

Soil contains organic nutrients, minerals, micro-organisms, water and oxygen, all of which are vital for good plant development. It also has a natural porous or sponge like 'structure' formed by the pore space within it that allows water to drain through. This soil structure is the part most likely to be damaged by poor handling or by being handled in poor weather conditions. Compaction caused by heavy machinery, particularly in wet conditions, can create solid impermeable layers in the soil, which then loses its ability to infiltrate water. Soil can also be damaged by pollutants (oils, cement or other site materials), by sediments, heavy runoff causing erosion, and by allowing heavy infestations of weeds to develop especially if stored for a long time.

To ensure soil is maintained in good condition, it should be stripped and stored in appropriate weather conditions.

The soil heaps should have their temporary plant cover sprayed out a week in advance of its intended reuse. The heaps should be opened up several days before use where stored higher than 1.5 metres. Soil testing should be undertaken by an approved soil testing laboratory. This will ensure that nutrients lost during storage can be replaced by incorporating appropriate quantities and type of organic or inorganic fertilisers and at a rate appropriate for the specified plants or grass.

1

Getting it right

Area to be used for soil storage heap should be free draining and not prone to flooding, site or sediment flows, or be close to an area used for disposal of site-waste materials. Soil should not be sited within the protected root zone of retained trees.

What can go wrong

Soil structure and nutrient content can be damaged by flooding.

Site waste could contaminate soil and prevent plant growth or kill plants.

Soil heap could damage the root zone of retained trees.



Soil poorly and inappropriately stored within retained tree root zones

2

Getting it right

Area for soil heap should be cleared of weeds or other site materials before depositing soils.

What can go wrong

Contamination can occur by perennial weed roots – even very small fragments of root can infest stockpiles.



Area designated and prepared before soil is deposited

3

Getting it right

Ensure that soil stripping and stockpiling is not carried out in very wet conditions.

What can go wrong

Soil structure damaged and soil organisms killed.



Soil stripped and deposited in good weather conditions

4

Getting it right

Ensure topsoil is not contaminated by other excavated site materials.

What can go wrong

Quality of topsoil is reduced and will require remediation/screening before use



Topsoil contaminated by other materials and poorly stored

5

Getting it right

Soil is laid in layers not exceeding 600 mm, and lightly consolidated. Height no greater than two metres overall.

What can go wrong

Soil structure can be damaged and soil organisms killed.



Heavily compacted soil lacks oxygen and soil organisms (grey colour). Soil structure has been damaged

6

Getting it right

Shape soil heap to shed water at gradients (ideally) no greater than 1 in 2.

What can go wrong

Water ponding on top of heap can cause washouts.



Topsoil stockpiled at steep gradient to shed water

7

Getting it right

Where soil is to be stored for an entire growing season (March to September), soil heap is sown with a clover or low maintenance grass seed mix to prevent weeds growing and seeding on it.

What can go wrong

Soil becomes contaminated with weeds (root fragments or seeds), causing weed problems when reused on site.

11.3 CHECKLIST FOR MANAGING SITE SOILS

The following list should be used as the basis for on-site checks, but should be amended to suit the site requirements and its specification.

TABLE 11.1 Pre-construction checklist ✓

Location of soil heap is appropriate, and not subject to surface water flows, site sediments or silts	
Area for soil stockpile has been cleared of weeds and/or other site materials before depositing soil	
Weather conditions before stripping and stockpiling operations, and cease activities during and immediately after heavy rainfall	
Overall height of soil heap is no greater than two metres, profile to shed water, angle of bank slope (ideally) not greater than 1 in 2, and that it is adequately consolidated, but not compacted	
Soil heap has been sown with a ground cover, and that cover is adequate to prevent weed infestation	
Outcome of soil test before reuse and that appropriate fertilisers are used to improve the soil to the specified standard	

CASE STUDY 11.1

Influence of tree protection zones on soil storage



Figure 11.7 Excavated soils being stored within root protection zone of mature trees

During the construction of wetland cells within a residential area, extensive ground works were required. Soils were excavated, stripped, stored and spread across a large area of the site. With many mature trees in the area, this added complexity to where excavation, storage and spreading could take place (to avoid damaging the tree roots).

Excavated soil was found to have been stored in the root protection zones of trees on the site. This was because protective fencing had not been erected around the trees before works started.

This was only for short-term soil storage, so the issue was later resolved as part of wider soil spreading works within the ground works programme. If it had been for a prolonged period, it could have caused significant damage to the trees. Fortunately, despite their treatment, the trees did not show noticeable signs of damage in either the short- or long-term.

Lessons learnt

- Tree protection fencing should be installed on site before development starts to ensure vehicle access and storage is restricted within tree root protection zones.
- Contractors should be fully aware of site restrictions and the effects of storage within root protection zones.

Jargon buster

- **Infiltration** is where water is allowed to soak into the ground.
- A **tree root protection zone** is the area around the base of a tree that contains sufficient root volume to ensure the future well-being of the tree in the event of nearby soil disturbance. Works in this zone must not cause damage to the tree roots.
- **Soil structure** is the arrangement of the solid parts of the soil and of the pore space located between them.
- **Engineered soils** are soils that are designed and manufactured to provide specific drainage and horticultural properties.



12 SUDS AND SITE ACCESS

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12.3 Using permeable sub-base construction for site access 59
12.4 Working over geocellular tanks at shallow depth or covering a wide area 61

Chapter 12

SuDS and site access

This chapter provides information on the challenges that may arise when using SuDS for construction access, and how to avoid them.

- *General construction checklists are provided in Appendix A1.*
- *General good practice guidance on the construction of SuDS schemes can be found in The SuDS Manual (CIRIA C753) Chapter 31.*

12.1 INTRODUCTION

In general, pervious surfaces should not be used for construction access, due to the potential damage that could be caused to them by site traffic and muddy or polluted construction site runoff. However, where main site roads have to be designed as part of the SuDS, methods can be used to allow for their partial construction, and for the temporary surfacing to be sufficiently remediated before final surfacing layers are laid.

Geocellular tanks can be damaged by construction traffic, especially if at shallow depth. The risk of damage should be assessed and where necessary precautions should be taken to protect them.

12.2 TRADITIONAL DRAINAGE VERSUS SUDS CONSTRUCTION

Traditional drainage is usually constructed early in the programme and then covered, which protects it from damage during construction. Drainage and roads are usually constructed and used by developers in the following sequence:

1 Surface water drainage and roads/car parks are constructed (but the final surfacing is usually left out and constructed at the end of the project).

2 The partially completed roads are used for constrution access, parking areas and materials storage.

3 On completion of the building works, the temporary surface is cleaned (and repaired if necessary) and the final wearing course laid.

There is little restriction on the use of cranes or other heavy machinery by presence of surface water drainage.

In contrast when roads within a development are drained by SuDS components such as pervious paving or shallow geocellular tanks, particular care has to be taken to prevent clogging or damage if they are to be used for access by construction plant and vehicles.

12.3 USING PERMEABLE SUB-BASE CONSTRUCTION FOR SITE ACCESS

Permeable sub-base and road surfacing should be protected from mud and muddy water from the construction works as these will clog up the permeable finish. However, where the use of the permeable sub-base is necessary for construction access, this can be planned into the process to ensure it remains in good condition, until the final stages of works when it can be remediated and the final surface finish laid.

A common approach is to lay the permeable base layer and cover it with asphalt to provide a strong, temporary road surface. When muddy site works are complete, the surface should be thoroughly cleaned using road sweepers, and then large holes cored out evenly across the entire surface (see **Figure 12.1**), after which the final block or other permeable surfacing can be laid.

Another option is to cover the permeable sub-base with a geotextile and then lay a temporary cover of normal sub-base on top of it (**Figure 12.2**). At the end of the main construction works, the temporary sub-base is removed and the final surfacing constructed.

A third option is to construct the capping layer in normal materials and use the capping layer for construction traffic. The pervious pavement (sub-base and surfacing) is constructed at the end of the construction programme. A geomembrane will be required to protect the capping laying from water infiltration, so this approach is not suitable for infiltration systems where water has to soak through the bottom of the sub-base into the ground.

Figures 12.3 to 12.5 show typical sections for each approach to protecting the sub-base. The right hand side shows the section during construction and the left hand side shows the completed works.



The layer of asphalt is cleaned before coring to prevent mud/site material blocking permeable base, and then filled with granular material to allow drainage, before final permeable finish

Figure 12.1 Cleaning the asphalt layer before coring



Figure 12.2 Sacrificial sub-base layer allows use of permeable sub-base for parking during construction

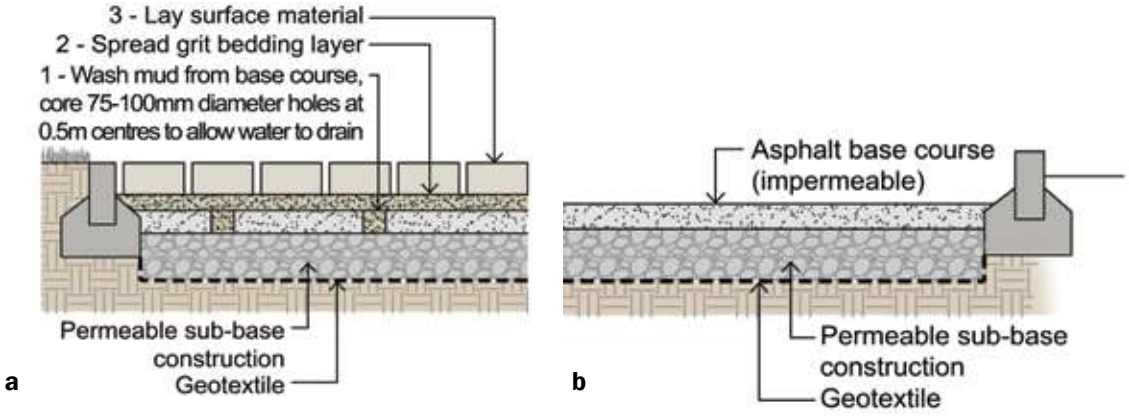


Figure 12.3 Cored asphalt base course completed (a) and during construction (b)

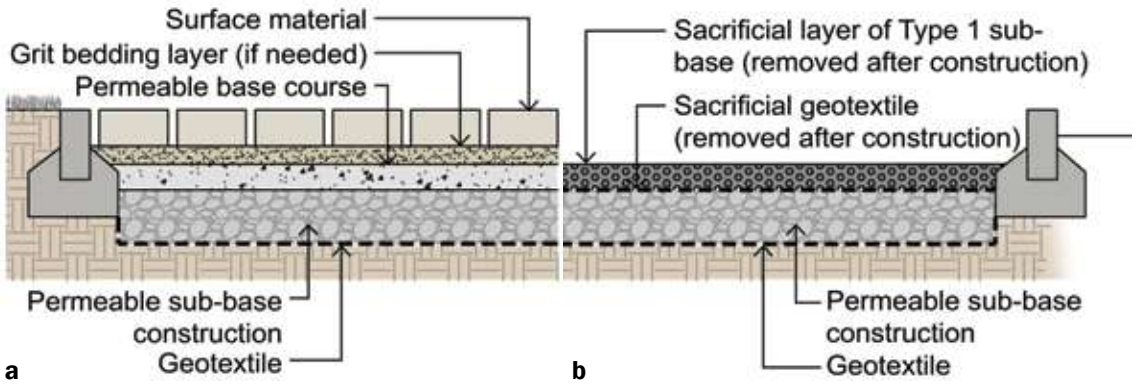


Figure 12.4 Sacrificial geotextile completed (a) and during construction (b)

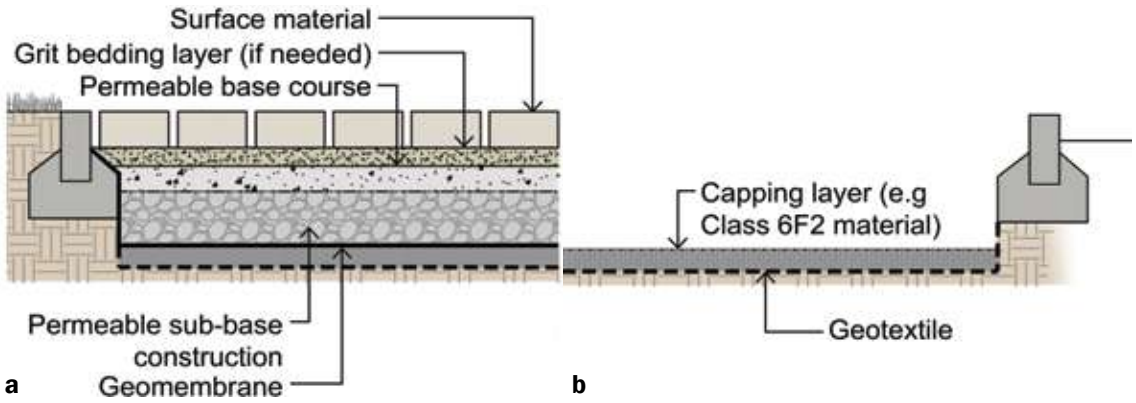


Figure 12.5 Using a capping layer completed (a) and during construction (b)

12.4 WORKING OVER GEOCELLULAR TANKS AT SHALLOW DEPTH OR COVERING A WIDE AREA

There is a need to consider whether heavy machinery and plant can operate over underground storage tanks. This may require:

- fencing around tank locations to stop vehicles trafficking over them
- preparation of site-specific risk assessment and load calculations for a full range of site plant including cranes, cherry pickers etc to make sure they do not overload the tanks.



Figure 12.6 Appropriate use of fencing to prevent vehicle access



Figure 12.7 Risk assessment checklist

CASE STUDY 12.1

Construction loads on an attenuation tank

Following the installation of a below ground attenuation storage tank, a loaded six tonne dumper and 7.5 tonne excavator required access onto the tank to place drainage before completion of the works. There was only a 500 mm thick layer of compacted 6F1 material on the tank at the time. The guidance in the user manual from the attenuation tank supplier indicated that the following cover was required for in-service traffic loads:

- 500 mm ground cover sufficient for traffic loading up to 2.5 tonnes
- 1000 mm ground cover sufficient for HGV loading up to 44 tonnes (assumed wheel load 4.5 tonnes).

As these were in-service traffic loads that took account of the impact on the tank of the surfacing material (eg asphalt), they may not have been applicable during construction. The six tonne dumper and 7.5 tonne excavator were also not specifically covered. So, a site-specific structural load capacity check was carried out.

The calculations showed that the six tonne dumper would result in the largest pressure on the tank. As this did not exceed the short-term vertical characteristic strength of the tank (with appropriate factors of safety) the construction traffic would be acceptable because the final surfacing had not been placed, so the effect of deflection on the surfacing was not a concern.

However, despite these load calculations indicating that the vehicle load would be acceptable, the contractor decided to protect the tank in line with manufacturer's in-service recommendations. So it was necessary to lay an additional 250 mm thick compacted 6F1 material thereby providing 750 mm.

Lessons learnt

- It is vital to plan ahead within projects to schedule appropriate vehicle access and when unexpected circumstances require vehicle access, check this can be done safely. In-service requirements for cover depths may not be appropriate during construction, but should always be checked with site specific calculations.

Jargon buster

- **6F1** is a type of capping layer material as described in DfT (2009).
- A **sacrificial layer** or material is provided as a temporary measure during construction and is removed before the works are completed.



13 MANAGING EROSION AND SILT ON SITE

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13.4 Good practice checklists 70

Chapter

13

Managing erosion and silt on site

This chapter provides information on preventing challenges arising on site due to erosion and silt.

- *A construction checklist for dealing with erosion and silt is given in Section 13.4.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on managing erosion and silt (sediment) can be found in The SuDS Manual (CIRIA C753) Chapter 31.*

13.1 INTRODUCTION

Erosion causes the release of mud, silt and damage to SuDS. Deposition of silt (from erosion of the SuDS or construction site runoff) causes blockage and contamination surfaces. It can also reduce the capacity of SuDS to convey and store water. It is important to manage site runoff carefully, as failing to do so can cost considerable time and money to reinstate areas that become damaged.

Water will flow into a SuDS component as soon as downpipes, road gullies, channels, etc are connected to it. Where a component has its base and slopes formed from soil, water will wash away the soil if grass and plants are not sufficiently established to form a dense matted cover that will prevent erosion. If it is necessary to allow surface water into newly constructed SuDS when the planting is not fully established, then some form of erosion control will be needed.

Runoff from a construction site is generally muddy. If the SuDS are used to drain a site during construction, the mud (silt) will collect in the system. If it is not removed at the end of construction, the build-up of silt is likely to cause future blockages and possibly flooding. It also looks unsightly. It is important that mud/silt is managed during construction and is removed from the SuDS before its completion (see **Part G Case study 37.2**).

However, SuDS that are designed to infiltrate, such as infiltration basins or swales, should not be used for temporary site drainage as the silt found in site water runoff is likely to destroy the soil's ability to infiltrate. Similarly, the permeable sub-base and finished surface of pervious paving should also be protected. Both problems are very difficult to remediate.

Finished parts of SuDS may need to be protected from construction runoff. For example, an area of pervious surfacing may not have construction traffic running on it, but could have cars trailing mud onto it from other muddy roads on a site. Mud from the roads could also be washed into adjacent completed components such as swales, potentially damaging them.



Figure 13.1 Mud being spread by vehicles from soft surfaces onto permeable paving



Figure 13.2 Muddy runoff washing into SuDS

13.2 CHALLENGES RELATED TO MANAGING EROSION OF SUDS

These challenges primarily occur on slopes, or where the velocity of water is strong enough to cause erosion. Where erosion of the soil surface occurs, silt is washed down the system and surfaces are damaged.

1

Getting it right

Make sure all areas of the SuDS are ready to receive water before allowing it to flow into them. Use turf on areas of soil intended to take water if they need to be used before they become fully established and pin it down.

What can go wrong

Erosion of banks and bed could occur if planting is not established or erosion protection not supplied.



Grass to base of swale failing due to lack of time to establish

2

Getting it right

Use erosion control mats or fencing over higher/ steeper side slopes to allow grass or other vegetation to establish. (Note this also applies to soil slopes near to SuDS, especially pervious surfaces, to prevent soil washing onto the surface).

What can go wrong

Soil erosion through washouts down slopes, which can also damage planted areas on the slope. Gullies form, and plants or paving become buried in silt at the foot of the slope.



Washout from banks causing silt build up on paths

3

Getting it right

Use erosion control blankets and mats designed to deal with the anticipated speed of water.

Ensure surface is free of obstacles.

Install erosion protection products in accordance with supplier's instructions. Provide sufficient subsoil below mats and pin them down on slopes to provide a stable surface.

Provide an anchor trench at the top if necessary.

Allow sufficient overlap between sheets and staple together if necessary.

What can go wrong

If surface is insufficiently prepared and the blankets are not installed and pinned correctly, water can flow behind them causing erosion. Incorrect preparation of surfaces (not even enough or too smooth) may result in slippage. This can also occur if the sheets are not sufficiently anchored.



Surface unprepared and matting poorly fitted resulting in erosion behind mat

4

Getting it right

Use hydroseeding particularly on slopes, with a mixture of fibre, seed, fertiliser and stabilising emulsion.
Ensure the slope is properly roughened so the mix sticks to it. Ensure the coverage and mix is as specified. Allow to germinate and establish fully before allowing water to flow over it.

What can go wrong

If mix is not allowed to establish it will quickly wash out once water starts to flow through the system.



Washout of hydroseeding leaving slopes with little vegetation establishment

5

Getting it right

Where possible allow sufficient time for grass and planting to establish before its use within the SuDS – both planting and grass are much slower to establish in winter.

What can go wrong

Wash out plants or areas of grass if used where erosion occurs and if there is insufficient time for vegetation to establish.



Poor establishment of planted vegetation due to excessive erosion before establishment

6

Getting it right

Use temporary check dams in swales to reduce flow velocity and trap silt.

What can go wrong

Erosion occurs along flow path.



Rocks slow velocity and trap silt – can be temporary or permanent



Handy hint

Use turf and pin it down to prevent slippage if areas need to take water before the grass has fully established.

13.3 CHALLENGES RELATED TO MANAGING SILT

Silt can arise from erosion in the SuDS or from nearby areas of soft landscape and from general muddy water on site.

1

Getting it right

Keep areas of exposed soil near to the SuDS or draining towards it to a minimum.

What can go wrong

If soils are not protected or established with vegetation, erosion will occur causing silt to be washed out.



Soil washed down slope, creating flow channels

2

Getting it right

Where earthworks leave exposed soil, form slopes to collect water in temporary areas where silt can be managed. Alternatively use silt fences.

What can go wrong

Erosion will occur causing silt to be washed out.



Using SuDS basin to collect silt

3

Getting it right

If the permanent SuDS are used for drainage of construction runoff then make sure all silt is removed at the end of the job.

What can go wrong

It is more difficult to establish grass or planting on deep areas of silt. Levels are unlikely to be correct due to silt build up.



SuDS at end of construction with silt build-up, which had to be removed (and re-graded) before final planting

4

Getting it right

Prevent muddy water from flowing onto pervious surfaces or into bioretention systems.

What can go wrong

Silt will clog and damage pervious finishes.



Muddy water clogging pervious pavement



Sand bags surround inlets to bioretention planters

5

Getting it right

Prevent muddy water entering geocellular tanks or other SuDS that are not on the surface (unless they have good provision for cleaning out, but still undesirable). Protect gullies with sand bags, straw bales or similar.

What can go wrong

Silt can clog up the system or reduce available storage space.

6

Getting it right

Ensure runoff from fresh concrete is diverted temporarily (eg using sand bags).

What can go wrong

Runoff from fresh concrete can contain a lot of cementitious material, which can damage planting, and/or harden and clog a system, potentially causing flooding or reducing storage capacity.

7

Getting it right

Use mobile silt catchment systems, which process water pumped through them, allowing silt to settle where it can be removed.

What can go wrong

Silt may continue through several parts of the SuDS, settle and decrease functioning of downstream components.



Silt buster

Handy hint



Consider using a temporary SuDS basin to collect site runoff and silt.

13.4 GOOD PRACTICE CHECKLISTS

The following lists should be used as a basis for on-site inspections. Note that they should be amended to suit the particular site requirements and its specification.

TABLE 13.1 Pre-construction checklist – managing erosion ✓

Planting is properly established before allowing water to drain through it or that turf is partially established and well pinned down	
Erosion control matting is used on steep slopes where problems are likely to occur	
Slopes are well prepared to receive matting	
Matting will deal with velocity of water anticipated	
Anchor trenches are used and adequately sized	
Matting is properly lapped, pinned and stapled	
Hydroseed mix and application rate is correct for site location as specified	
Slope is properly roughened to receive hydroseed	
Temporary check dams are necessary to reduce velocity during establishment	

TABLE 13.2 Pre-construction checklist – managing silt ✓

Exposed soils either in the SuDS or next to it are not washing out and causing silt problems	
Silt fences or temporary silt basins are required to manage on-site silt and provide where necessary	
Where SuDS are used to hold silt temporarily, they are cleaned out before final planting or seeding	
Protection is in place to prevent silt washing into pervious paved areas	
Protection is in place for all underground storage systems and they have provision for cleaning	
A mobile silt catchment plant is necessary	
Runoff from fresh concrete is managed to prevent damage to SuDS	

CASE STUDY 13.1 Soil erosion due to poor earthworks management



Figure 13.3 Rainwater runoff down re-graded slope causing washoff of soil and wildflower seed

A landscape scheme involved large amounts of cut and fill on a steep slope to accommodate paths and other features, including a swale. After re-grading work and re-vegetation of the slope, soil erosion occurred with large amounts of fines washed off. This occurred predominantly due to vegetation not being adequately established before it rained. Although a geotextile membrane was used on the slopes for soil reinforcement, the slow establishment of wildflower seeding (sown during winter, out of season) did not bind the soil adequately, and the seed was washed out of the soil.

To solve the problem, areas that suffered severe washout were turfed and the top seeded with wildflowers (although this is not very effective). Areas with less severe erosion were reseeded.

Lessons learnt

- The client requested wildflower seeding, however because of the time of year this shoud not have been undertaken as it was unlikely to germinate. In this case it was not a practical option and should not be undertaken in winter. The client should have been offered appropriate alternatives.
- Ideally the wildflower seeding should have been carried out in spring or early autumn, and areas of exposed soil kept to a minimum.

CASE STUDY 13.2

Managing cementitious runoff

Runoff from a fresh concrete surface contained cementitious materials. The runoff then collected in a treatment channel and was not removed. Once hardened, the concrete clogged the outlet to the system, and the site continued to flood every time it rained. Removal of the hardened silt from the channel and outlet solved the problem.

Lessons learnt

- Measures (such as temporary drainage or regular cleaning out during construction) should be well planned and carried out to avoid cementitious or other construction waste materials from entering or hardening in SuDS components.



Handy hint

Where areas need to be brought into use early (or out of the seeding season), use turf (wildflower turf is also available, but there is a limited supply). Conventional turf can then have wildflowers 'plugged' into it to improve species diversity.

On slopes, turf may be laid along the contours in bands to prevent erosion while the seed between establishes. In the short-term, this will produce a 'stripy' effect due to the different species mixes, but the species in the two areas will gradually amalgamate over time.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Infiltration** is where water is allowed to soak into the ground.
- A **swale** is a SuDS component that is similar to a wide shallow ditch, but with a flat bottom.
- A **silt fence** is a temporary fence made from geotextile that is anchored into the ground to prevent water flowing under it. The silt fence is placed in the path of runoff and traps silt that is eroded.



14 ESTABLISHING PLANTING

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Chapter 14

Establishing planting

This chapter provides information on the challenges that may arise when establishing planting and how to avoid them.

- *Detailed guidance on a range of landscape issues including re-grading, soil reinforcement and planting can be found in The SuDS Manual (CIRIA C753) Section 29.3.*

14.1 INTRODUCTION

When used in SuDS, planting often has a major functional role as well as being an attractive part of the scheme. Grass and planting are key parts of delivering the over-riding SuDS principle of delivering 'maximum benefit'. They can also help slow the flow of water, facilitate infiltration, deliver improvements to water quality, provide greater biodiversity, as well as creating and enhancing the quality and appearance of a site.

Why should grass and planting be established early?

To be fully effective, grass and planting need to be well established before high flow rates of water enter the system, otherwise it can lead to erosion and washouts, with planting potentially needing to be replaced and sections of grass reinstated. This is more difficult to do once the system is fully functioning.

How does grass and planting improve water quality and biodiversity?

Grass and planting improves the runoff quality by filtering out silt and sediment, by capturing and then breaking down hydrocarbons and by locking up heavy metals within the plant material as the water physically moves through the vegetation. Planting can improve biodiversity and support a wide range of species. Damp ground is usually less intensively managed than other planted areas, and invariably has a wide range of native and naturalised species, which provide shelter, food and a suitable environment for birds, reptiles and invertebrates. This is important because damp/wetland environments are increasingly scarce.

Why do plants in SuDS die?

More plants die from waterlogging than drought, although both can cause failures. In the early days of establishment all plants can be vulnerable to drought, and so may require watering. Waterlogging can be caused by compacted soils leading to poor drainage, so proper ground preparation is important. Also, waterlogging can occur if construction is poor, eg incorrect ground levels, which results in standing water.

Wetland plant species are tolerant of damp or wet conditions, but those used in bioretention systems need to be drought tolerant, as the system is normally dry. So, ensuring the right plants are supplied and used in the correct places is vital. Compaction of the soil on its own can also adversely affect plants and cause poor growth. This is especially relevant to tree roots.

14.2 PLANT ESTABLISHMENT – GETTING IT RIGHT

There are five stages to good plant establishment that, if not considered, can lead to failure or poor survival rates:

1 Construction planning and preparation.
2 Planting, seeding and turfing on site.
3 Protection during and post implementation.
4 Maintenance pre-handover.
5 Handover.



Figure 14.1 Setting out and spacing of plants before approval and planting

It is particularly important to ensure that all other works are completed before planting, seeding or turfing to prevent damage from other construction activities.

TABLE 14.1 Factors to consider for successful plant establishment

Stage	Things to consider	Getting it right
Planning and preparation	Plants will only grow during certain times of the year	Grass seed will generally only germinate between April and early November.
		Turfing can be undertaken at most times throughout the year if the ground is not frozen, waterlogged, or excessively dry. Avoid turfing during hot, dry periods/drought.
		Planting stock that has been grown in containers (or specially prepared) can be undertaken at most times throughout the year if the ground is not frozen, waterlogged, or excessively dry. Avoid planting during hot, dry periods/drought.
		Bare root or root-balled shrubs and trees will only be available in the winter – typically end of November through to March (but varies with the weather conditions). Planting can be undertaken if the ground is not frozen or waterlogged.
	Other works in planted areas not complete	Check that all services/lighting or other installations are complete before the final groundworks and planting.
	Maintaining good soil condition	Ensure all compacted areas have been ripped to provide suitably free-draining soils.
	Plant supply and storage	Have all the plants been pre-ordered to ensure the right species at the right time? The plants required are not necessarily available all year round, so need to be ordered in advance.
	Plant substitutions	Seek advice from a landscape professional if some plants are not available, to ensure substitutions are suitable for their location.
Planting, seeding and turfing	Ground preparations	Ensure all ground preparation is completed in accordance with the specifications to provide the right ground conditions for both plants and grass establishment. Do not undertake when ground is frozen or waterlogged.
	Setting out and planting	Plants should be set out in accordance with the planting plan and checked by a landscape professional before planting.
	Plant establishment (or watering)	Check that the correct species are delivered to site in the correct quantities, to the sizes specified. All plants should be watered on completion of planting and weekly, unless conditions are cool and wet, from the end of May until September.
	Turfing	Peg turves on banks to prevent slippage or where water flow would move them before rooting down.
		All turf to be watered on completion of planting, and every two days unless conditions are cool and wet for the first two weeks. Reduce to weekly for further month.
Protection	Protect from physical damage	From other works, and from inadvertent access/trampling/ machinery.
	Protect from silt, muddy runoff or site waste/pollution	Ensure protection in place to avoid damage to establishing vegetation.
	Protect from surface water runoff	Ensure temporary site drainage in place to avoid runoff entering system until planting is established.
Establishment maintenance	Planting	All plants to be watered weekly unless conditions are cool and wet, from the end of May until September.
	Weeding	Weeding undertaken monthly to reduce competition for water.
	Turfing and seeding	All turf to be watered weekly after first month for a further month unless conditions are damp and cool.

TABLE 14.1 Factors to consider for successful plant establishment (contd)

Stage	Things to consider	Getting it right
Establishment maintenance	Turf and grass cutting	Once good ground cover is established, cut weekly for next month to encourage a thick dense cover.
	Wildflower grass cutting	Cutting in accordance with supplier recommendations for specific wildflower mix – likely to be three to four times in its first year to ensure it establishes properly.
Handover	Repair defects and carry out inspection of the works before handover	Check that all plants are properly established and failures have been replanted, and then allow time to become sufficiently established.
		Check that all beds are free from both annual and pernicious weeds.
		Check that mulches as originally specified are in place and in good condition.
		Check that all stakes and ties to trees are in place and correctly adjusted, and that watering systems are functioning correctly.
		Check that all grass areas have a good quality, dense sward of the correct species mix, and that it is being maintained to the correct height and frequency of cut as defined in the maintenance specification.

CASE STUDY 14.1 Changes to the design by a contractor



Figure 14.2 Vegetation mat starting to disintegrate, and poor vegetation establishment

The design for a swale required that the side slopes were excavated and the sub-soil covered by a layer of topsoil. The design required a 'pictorial meadow' planting mat to be placed over topsoil. The contractor did not follow the design and topsoil was not provided or prepared in accordance with the specification. This was not picked up because of a limited inspection regime. The absence of topsoil caused the vegetation establishment to be patchy and the mat quickly began to disintegrate leaving strands of plastic littering the swales, basins and wider site.

Eventually, the vast majority of the vegetation mat had to be removed in those areas where establishment was poor, with more topsoil brought in and the affected areas re-planted directly into the ground. The planting then established well.

Lessons learnt

- Ensure that sufficient topsoil is provided below any planting mats.

CASE STUDY 14.2

The effect of compacted soil on trees



Figure 14.3 Line of failed trees

A soil and landscape science consultancy was asked to investigate dying trees in a school academy development in south-east London. A line of trees had been planted, but had since died. Soil investigations revealed that although an adequate size and depth of tree pit with appropriate soil mix had been provided, the surrounding sub-soil was overly compacted due to the site's previous use as a site compound. This resulted in water infiltrating through the surrounding topsoil and collecting in the tree pit. The compacted sub-soil had a low permeability and this caused the water to stand in the tree pit, submerging the roots. The long-term presence of water around the tree roots resulted in the failure of the trees due to a lack of air reaching their roots.

Lessons learnt

- Although the development appeared well designed, the standard of implementation and poor consideration of sub-soil conditions resulted in the death of trees. A thorough investigation of soil conditions before construction and possibly provision of drainage could avoid such problems.



Watch point

Check that all services/lighting or other external works items have been installed before planting, turfing or seeding to prevent damage to plants and topsoil.

Should exceptional or unseasonal weather conditions occur, check with the landscape designer regarding the need for watering or other remedial actions.

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Constructing and inspecting SuDS





15 INTRODUCTION TO PARTS E AND F

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Chapter

15

Introduction to Parts E and F

This chapter provides information on how to use Part E and its relationship to Part F.

- *General construction checklists are provided in Appendix A1.*
- *General good practice guidance on the construction of SuDs can be found in The SuDS Manual (CIRIA, C753).*

15.1 INTRODUCTION

Parts E and F work together and cover all aspects of SuDS construction and the challenges in building various SuDS components:

Part E discusses general issues that may potentially affect the successful construction of SuDS. These range from the effect of variations, to the inspections required, and advice on subjects such as tolerances in constructing or dealing with high groundwater.

Part F explains the challenges in constructing individual SuDS components. It identifies what should be done to ensure they are built correctly, and what is likely to go wrong if not. Each chapter deals with a different component, and briefly explains the variety of challenges that can occur for each one, depending on design approaches.

Within each component chapter, the challenges of construction are explained by considering what is needed for **'getting it right'** and **'what might go wrong'** if construction is not carried out correctly. The explanations are kept short, and where possible, images are provided either of that particular problem on site or of a correctly constructed component. At the end of each chapter there is a checklist to be used as part of the construction and inspection process for that component. For most components, this is followed by a case study to explain how and why a particular problem occurred on site, and how it was rectified. The checklists for all components are found in **Appendix A1** and are available to download from the susdrain website: **www.susdrain.org**

The chapters for each component have been designed so that they can be downloaded individually and used as a reference on site as each one is built.

15.2 WATCH POINTS, HOLD POINTS, HANDY HINTS AND JARGON BUSTERS

The following chapters also contain ‘watch points’, ‘hold points’ and ‘handy hints’, which are identified as follows:



Hold point

Identify points in the construction process where the works should be inspected before continuing with their construction, failure to inspect could significantly affect performance.



Watch point

Identify potential problems to be particularly aware of, as they frequently occur for that component or aspect of construction.



Handy hint

Anticipate problems, so they can be avoided, or offer a simple solution to a common problem, which may be useful.

Jargon buster

Explain the less well known technical terms that are used in the guidance, for example:

- A **component** is a drainage feature that can take many forms.



16 INSPECTIONS DURING CONSTRUCTION

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Chapter

16

Inspections during construction

This chapter provides information on carrying out inspections during the construction of SuDS, when to do the inspections and what to look for.

- *General construction checklists are provided in Appendix A1.*
- *General information on construction checklists is given in The SuDS Manual (CIRIA C753) Appendix B6.*

16.1 INTRODUCTION

It is important that all critical aspects of SuDS are inspected during construction to confirm that the as-built system complies with the design. This is no different to traditional drainage or pavement construction. Adopting bodies, whether a sewerage undertaker, local authority or private company will want to know that they are not taking on responsibility and liability for poorly constructed systems. Inspections should be recorded and photographs taken of all critical stages of construction (see **Part G Case study 37.3**). It is wise for an adopting body to arrange their own inspections of work, either using in-house staff or external independent consultants, rather than relying on the contractor to inspect their own work.

16.2 PLANNING THE INSPECTIONS

The requirements for inspections of SuDS construction will be similar to those required by highways authorities with respect to adopting the highways, and sewerage undertakers adopting the foul sewers under various pieces of legislation (eg Section 38 of the Highways Act 1980 or Section 104 of the Water Industry Act 1991). There may be overlap depending on which organisation is adopting the SuDS. Before starting construction the inspector and the contractor should agree the key items that need to be inspected and likely construction/inspection dates. Everyone should be made aware of changes that are likely to affect dates when inspections are carried out.

The contractor should arrange to allow reasonable access to inspect relevant parts of the works at all reasonable times. Sufficient notice should be provided to the inspector when works are to be covered up. If work is covered up without being inspected it should be uncovered to enable it to be inspected.

16.3 WHAT TO INCLUDE

Most inspections are a visual record of construction along with measurement of sub-base depths, slope angles, checks that the correct materials or components have been used and installed correctly etc. Inspections may also include testing or observation of tests (for example pipe or membrane leakage tests or tests to determine the permeability of bioretention soils), sampling and laboratory testing or assessment of test data provided by the contractor's laboratory to show compliance with specification criteria. At the end of construction, a topographical survey of the system with as-constructed levels should also be completed.

16.4 RECORD OF INSPECTIONS

The inspections should be recorded on the relevant checklists provided in this guide. Overall the inspection reports will be site specific and should include the following as a minimum (as far as it is relevant to the item being inspected):

- Photographs of excavations, confirmation of soil conditions, confirmation of levels, profiles and general earthworks, and of the SuDS component before and after planting.
- Confirmation of subsoil and topsoil depths.
- Confirmation of source and laboratory test certificates for geosynthetics such as membrane liners if used. (Geomembranes should have welded joints and should be inspected and the joints tested after installation, see **Part E Chapter 22**). Records of the tests should be provided.
- Photographs and full manufacturer's details (if appropriate) of inlets, outlets and control structures and other components.
- Confirmation of material sources such as topsoil, aggregates, sub-base etc with appropriate laboratory test certificates.
- Confirmation of layer thickness in hard construction build-ups (eg sub-base thickness, laying course thickness, asphalt thickness).
- Details of remedial works required, particularly where SuDS are used for access or site drainage during construction (eg silt removal).
- Full planting list and confirmation of plant sources, planting method statement and initial maintenance regime.

Some or all of this information may be required for inclusion within the final handover manual (or Building Information Model) for the client or site occupier.

Jargon buster

- A **component** is a drainage feature that can take many different forms.



17 ASSESSING THE IMPACT OF VARIATIONS

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Chapter

17

Assessing the impact of variations

This chapter provides information on how to assess the potential impacts of contract variations on SuDS.

17.1 INTRODUCTION

Variations are a normal part of a construction contract, but some have the potential to seriously affect the performance, visual quality, maintenance regime or safety of SuDS. Variations should be reviewed both for their direct effect and their potential knock-on effect on entire systems, to ensure that either this does not happen or that risks are minimised.

17.2 QUESTIONS TO ASK

The following potential variations will need to be checked and confirmed by the original SuDS designer as appropriate, or novated/contractor or employed designer, who has a full understanding of the SuDS, how each part operates, and its overall expected design performance.

TABLE 17.1 Things to consider when addressing contract variations

Variation proposed	Check
Increase in hard surfaced area	Are the new areas pervious or impervious? Does the adjacent and downstream part of the component have sufficient capacity for an increased impermeable area? If the outflow is controlled to a specific discharge, then find out whether the control device needs checking/changing.
Changes in levels	Will the new SuDS gradients still work? Are the bank gradients stable and safe? Has the capacity and ability to manage runoff rates and volumes of the component reduced? If the area is permeable, will the change in gradient still conform to the maximum allowed for percolation through the surface? Changes in water levels will affect the performance of flow controls.
Additional cut material to be disposed of on site	Will it change levels or bank gradients to the SuDS? Will the drainage gradients still work? Will they still be safe and stable? Has the capacity of the component reduced? Is the additional material suitable/similar to other site soils?

TABLE 17.1 Things to consider when addressing contract variations (contd)

Variation proposed	What needs checking
Substitution of proprietary products or materials	Will these perform to the same standards as those originally specified? Are they as long lasting? Are there knock-on effects to other materials or the construction process that will increase costs? Are there more difficult or different maintenance requirements?
Substitution of plants or seed mixes	Will the substituted plant or grass species grow in the conditions likely to be found in the SuDS? Does the change of planting affect its visual quality throughout the year? Will the changes affect the agreed maintenance plan?
Changes in works programming/ sequencing of operations	Can the planting still be completed at the appropriate time of year? Will the necessary plants be available? Will they be able to establish sufficiently before the SuDS are used? Will seeding need to be substituted for turf in the base of SuDS if works are to be completed in winter?
Value engineering or inadvertent change	Will they affect the capacity/quality of the SuDS? Will its performance or safety be undermined? Will the changes affect the agreed maintenance plan or the service life?

Other unanticipated changes, such as the discovery of unmapped services, below-ground structures or contamination may also necessitate variations. Where such changes require a fundamental design change then the entire system should be re-evaluated by the designer to ensure it can still deliver the original design criteria for quality, quantity, amenity and biodiversity. These changes may also affect both the project programme and the nature of the works to be undertaken, so there may need to be a more comprehensive project review including the Construction Method Statement.



Watch point

Check whether contract variations will negatively affect the SuDS.

Value engineering or inadvertent change should not affect the storage capacity or quality of the system, its performance or safety. Value engineering should not be a cost-reduction exercise. The process should consider alternative solutions and identify and eliminate unwanted costs, while improving function and quality.



Watch point

Generally a component or proprietary system that conforms to a British, European or International Standard, or one that has been independently certified through a recognised national or international verification scheme, should be used in preference to an independent assessment of the supplier or manufacturers' claims. Where no independently-assessed components are available, it is important that the supplier or manufacturer's claims are assessed by the SuDS designer and/or approving or adopting body. Even where a system is certified by a national or international verification scheme (eg BBA certificates) the restrictions and requirements for use stated in the certificate should be assessed against the specific design. For example many BBA certificates for geocellular tanks have restrictions on the loads that can be applied to the tank and the depth of installation.

CASE STUDY 17.1

The impact of a contractor's design changes

A swale had been designed along the inside edge of a road enclosing the central green space of a small residential eco-development. The engineers had sized the swale to store 56 m^3 of water runoff from the road. The location of the swale was also a practical means of preventing cars parking on the green space. A 900 mm dished granite channel collected water from the adopted road surface (the only impermeable paving on the site), and was intended to spill down into the swale on the ground surface.

However, it was decided by site staff (for reasons unknown and without checking with the designer) that the channel, which was next to the swale, should first drain to a gully that would then connect to the swale by a pipe. However, doing so meant that the base of the swale had to be set 400 mm to 500 mm below the outfall, which made it deeper. This was unnecessary and expensive in terms of extra excavation and gully pots. It also potentially detracted from the safe use of the community green space and created a less attractive appearance.

Lesson learnt

- It is important to consult the original SuDS designer regarding design variations (and ideally that they are retained on the scheme) to ensure that the original design intent is delivered on site, and that changes do not compromise either safety or visual quality.

Jargon buster

- A **swale** is a SuDS component that is similar to a wide shallow ditch, but with a flat bottom.
- A **British Board of Agrément (BBA) Certificate** is a document that shows the fitness for the purpose of a construction product and its compliance or contribution to compliance with the various Building Regulations applying in the UK. BBA certificates are awarded to products that have passed a comprehensive assessment that includes laboratory testing, an on-site evaluation and production inspection. The certificates contain details of the physical properties, limits on application and installation procedures that must be followed.



18 HANDOVER INSPECTION

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Chapter

18

Handover inspection

This chapter provides a checklist of items to be confirmed on site at handover.

- *General construction checklists are provided in Appendix A1.*
- *General information on construction checklists are given in The SuDS Manual (CIRIA C753) Appendix B6.*
- *General guidance on adoption/handover checklists are given in The SuDS Manual (CIRIA C753) Appendix B9.*

18.1 INTRODUCTION

Before the SuDS are handed over to the client, adopting body or the end user, final checks should be undertaken to confirm that the system has been consistently checked throughout its construction, and that it delivers the planned water storage, water quality improvements, improvements to biodiversity and an attractive amenity landscape for the end users. Ideally, this should be carried out by an independent assessor.

18.2 GOOD PRACTICE CHECKLIST

Detailed checklists that can be used for documentary purposes are provided in **The SuDS Manual (CIRIA C753)**. The following simplified version may be used as an aide mémoire of what needs checking before handover.

TABLE 18.1 Final handover inspection checklist

	✓
All changes to the designed system have not affected the ability of the SuDS to deliver the quantity/quality/biodiversity and amenity requirements as originally designed	
Inlet and outlet levels are correct	
Structural components are as specified in the design	
Slopes are constructed to the correct gradients	
Correct planting/turfing has been installed and has established	
No uneven settling of soil, channelling, unwanted ponding or erosion of bed or side slopes	
No evidence of construction sediment or unexpected, rapid build-up of sediment	
Agreed access for maintenance is clear	
Site photographs of all key stages and a record of below ground works that are now covered up	
Test certificates	
Topographic survey of completed SuDS scheme	
Operation and maintenance plan for SuDS	
Other (TBC)	



19 TOLERANCES FOR SUDS CONSTRUCTION

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19

Tolerances for SuDS construction

This chapter explains the important factors about level tolerances that are appropriate in SuDS construction.

19.1 INTRODUCTION

It is not normally practical to construct SuDS to the exact dimensions and levels shown on design drawings. Tolerance is the allowable variation from the specified dimension or level. A wide tolerance can result in the system not working as required. One that is too tight may make the system extremely difficult to construct. If tolerances that are not the 'industry norm' are required by a designer this should be clearly stated on the design drawings.



Handy hint

Check the requirements for site-specific non-standard tolerances.

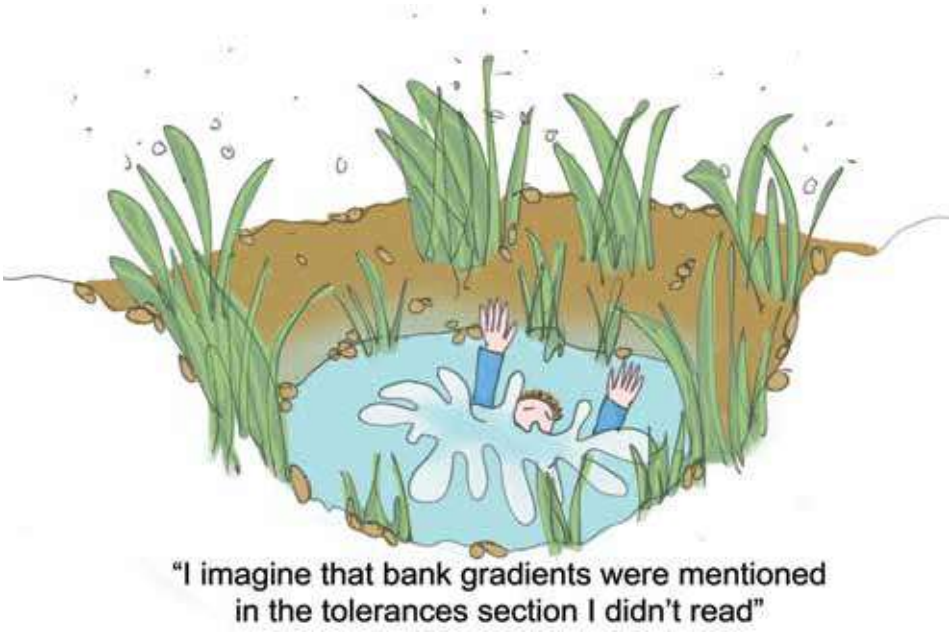


Figure 19.1 Check requirements for site specific tolerances

19.2 INDUSTRY STANDARD TOLERANCES

There are many industry-recognised tolerances that should be adopted for the construction of various SuDS components, as defined in the following sub-sections.

Surface level and surface regularity for pervious surfaces

Information on tolerances for the construction of concrete block permeable paving can be found in Interpave (2006).

The permissible deviation from the design level of the different layers is:

- sub-base +/- 20 mm
- road-base +/- 20 mm
- laying course +/- 20 mm
- surface +/- 6 mm when measured along a 3 m run.

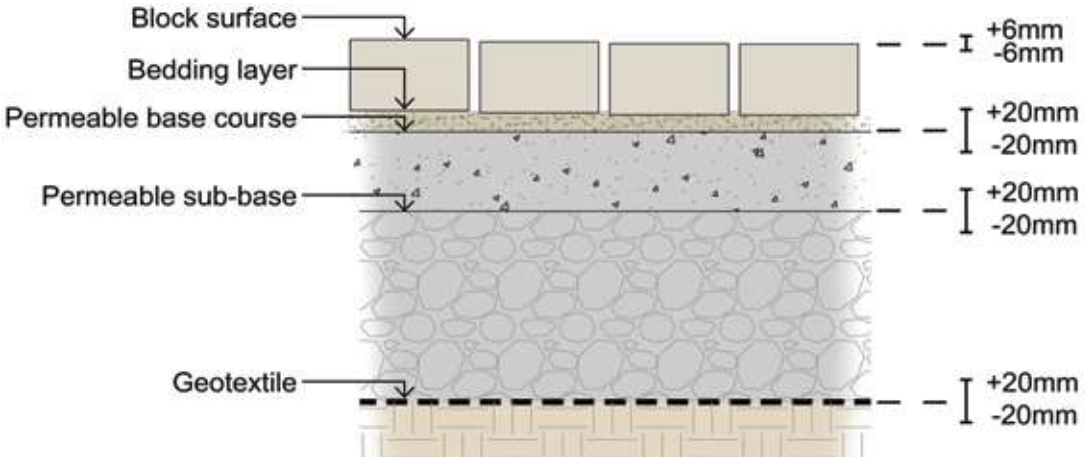


Figure 19.2 Tolerances for surface levels – pervious surfaces

The recommended surface regularity of the surface course is:

- Flatness of pavement (or undulation under a three metre straight edge) – appropriate to application, but not relevant to drainage performance. Normally 10 mm under three metre straight edge.
- Difference in level at joints of adjacent paving blocks or units 2 mm.

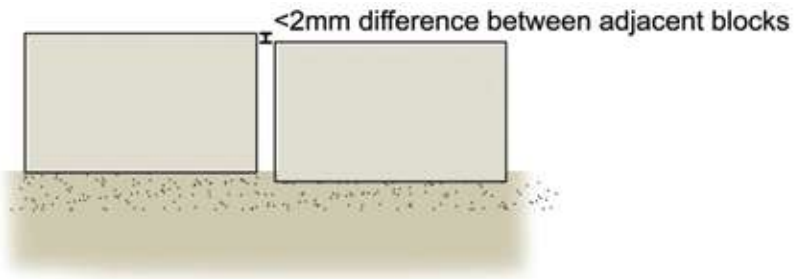


Figure 19.3 Surface regularity of surface course – pervious surfaces

The deviation in surface regularity of the formation where water drains through the sub-base to outfalls is +/- 20 mm (with the condition that no part of formation shall have a reverse gradient away from an outfall).

Note that tolerances for pervious sports surfaces will be set in the guidelines for each sporting body (eg SAPCA, 2007). Examples are provided in **Table 19.1**.

TABLE 19.1 Tolerances for porous asphalt tennis courts

Parameter	SAPCA (2007) Clause 2.10.1 and 2.15.1
Surface level	+/- 25 mm of theoretical true plane
Total foundation depth	- 25 mm Not less than 10 per cent design thickness over maximum of 10 per cent of court area.
Surface undulations	
Maximum gap below three metres straight edge	See SPACA (2007) For example, if construction comprises two or more layers of macadam maximum gap below a three metre straight edge on surface is < 8mm (see Figure 19.4).
No of permissible deviations	Four in principle playing area and eight in total playing area.

There are also limits on tolerances for the individual layers of asphalt in the construction as shown in Table 19.2.

TABLE 19.2 Porous asphalt layer tolerances for tennis courts

Material	Two course (recommended)		One course (only recommended for court subjected to light use)	
	Design nominal compacted thickness	***Minimum compacted thickness at any point***	***Design nominal compacted thickness***	***Minimum compacted thickness at any point***
0/6 mm surface course (tennis grade)	25 mm	15 mm	28 mm	25 mm
0/10 mm binder course	40 mm	30 mm	–	–
0/14 mm binder course	40 mm	30 mm	–	–
0/20 mm binder course	45 mm	35 mm	–	–

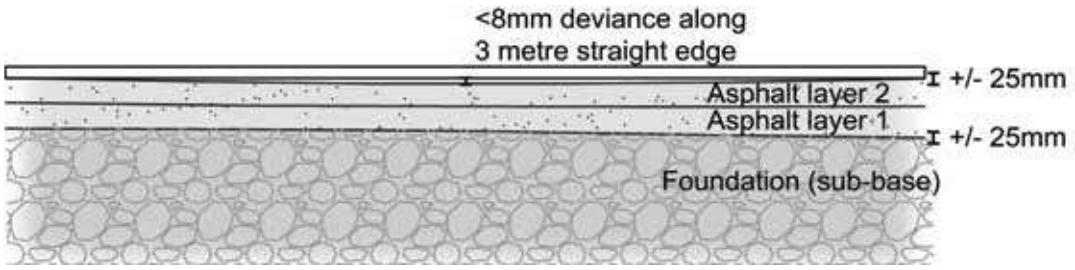


Figure 19.4 Tolerances for pervious sports surface (eg tennis courts surfaced with porous asphalt)

Tolerances for proprietary systems and attenuation tanks

The designers and/or the suppliers of the systems and tanks should be able to provide advice on tolerances. Contact them for further information before starting construction. The tolerance for pipe construction may be appropriate for many systems and tanks (discussed in the following sub-section).

Typically the base for geocellular attenuation tanks will require the most stringent tolerances to ensure that excessive stresses are not caused within the units or that gaps occur between the ground and the underside of the tank. A typical specification would be a limit for surface undulations +/- 20 mm over a three metre length. The tolerances on invert levels should be the same as those for pipes.

Tolerances for swales, basins, filter strips, wetlands and surrounding levels

There are no industry standard tolerances for the construction of landscaped areas. However levels for landscaped areas that also function as drainage components need to be constructed within tolerances to ensure that the drainage performs as required by the design. The following tolerances should be applied to the construction of swales, basins, filter strips, ponds and wetlands (and the surrounding levels as far as their impact on storage volumes and overflow routes):

- invert level of swale, basin or filter strip +/- 20 mm
- invert level of pond or wetland +/- 50 mm
- levels of slopes and surrounding area +50 mm
- swale centre line location +/- 50 mm
- surface undulation of base of swale, basin, filter strip maximum permissible gap below a three metre straight edge 20 mm.

Earthworks final surfaces for SuDS components should be completed to smooth alignments without abrupt irregularities.

Swales or filter strips should not have a reverse gradient at any point.

Tolerances for pipes, inlets, outlets and flow controls

The tolerances for pipe construction (WRc, 2007) are:

- pipe invert level +/- 20 mm
- pipe centre line location +/- 20 mm
- pipes should not have a reverse gradient
- joint displacement (difference in level or alignment between adjacent ends of two adjoining pipes – not to exceed the least of five per cent of nominal diameter of pipe or 20 mm).
- angular displacement of joint not to exceed 2^{o}.

The allowable tolerance for the level for a flow control is not defined, but a value of +/- 10 mm is reasonable.

Where water is allowed to flow over the edge of a hard surface into a filter strip or swale there should be a drop from the hard surface to the grassed area (see **Figure 19.6**). The difference in level shown in the design should be constructed to +/- 10 mm (**The SuDS Manual (CIRIA C753**) recommends a 50 mm drop, but some designers use 25 mm which may require a smaller tolerance).

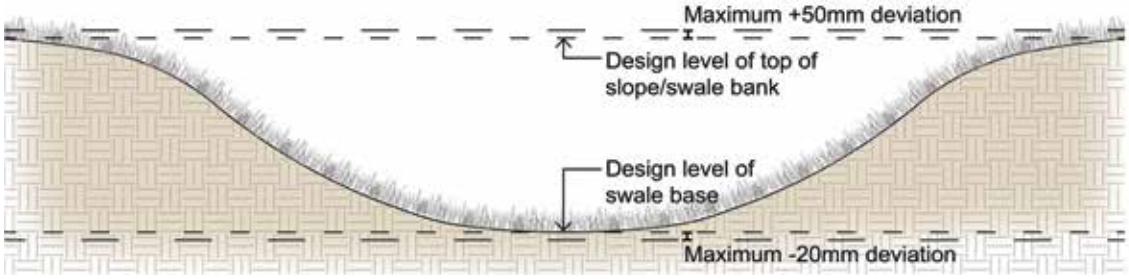


Figure 19.5 Swale invert levels

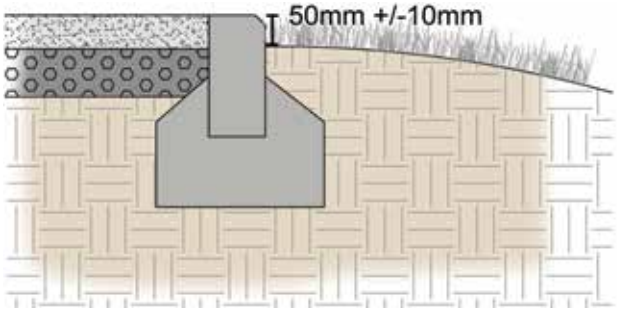


Figure 19.6 Over the edge drainage to swale or filter strip

Tolerances for paving and kerbs

Tolerances for items such as paved areas and kerbs that are not part of the SuDS may need to be integrated into the SuDS design, for example, where dropped kerbs lead into the SuDS.

DfT (2017) requires the surface level of units of kerbs, channels, edgings and quadrants to not deviate from the design level by more than 6 mm either way. The longitudinal surface regularity should not deviate more than 3 mm in three metres when checked with a three metre straight edge.

Tolerances on finished surfaces should meet the normal requirements for that type of paving or surfacing and should be less than the limits that indicate a defect (15 mm depth for a trip hazard is a typical value).

Handy hint



The dimensions of kerb and edging units (and other materials) will vary due to the limitations of manufacturing. For example, a 127 mm wide precast kerb unit has a width tolerance of ± 5 mm. So, the pieces delivered to site may measure between 122 mm and 132 mm. This needs to be allowed for when aligning the kerbs as there could be a maximum difference between adjacent units of 10 mm.

CASE STUDY 19.1 **Choosing the right tolerance**



Figure 19.7 Newly re-laid road set at lower level than inlet kerb, restricting surface water runoff from entering the SuDS

As part of an extensive SuDS scheme within a residential area, surface water runoff was collected from roads and directed into small swales. Water entered the swale through a stretch of dropped footway, across a dropped kerb and tumbled setts. However, a few weeks after the construction of the inlet the road surface was re-laid, but to a slightly lower level than when the inlet was constructed. This is normal practice when resurfacing roads. However, surface water ponded on the road surface before overflowing across the path and into the swale.

The road works were carried out without considering the effects of the resulting level changes, so the highways team agreed to re-adjust the levels on the road surface to lie flush with the dropped kerb, as originally designed and installed.

Lessons learnt

- It is necessary to ensure that relevant bodies understand the design and functioning of SuDS components installed on site, and the possible implications of their actions on their functionality.
- Even small level differences can affect the ability of a system to function correctly, so the checking of levels and their relevant tolerances is particularly important.
- If possible, the design should avoid requirements for excessively small tolerances that are difficult to achieve or are not normal practice.
- The design should consider the effect of future works carried out to normal requirements. Usual practice is to lay asphalt below the top of a dropped kerb. If a drainage inlet and bridging structure under the pavement had been used, the resurfacing contractor may have recognised it and laid the asphalt flush with the level of the inlet. A sign or image on the inlet may also have helped.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- A **swale** is a SuDS component that is similar to a wide shallow ditch, but with a flat bottom.
- **Permissible deviation** is the allowable level of variance from its original intention.



20 MANAGING SUDS CONSTRUCTION ON DIFFICULT SITES

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Chapter

20

Managing SuDS construction on difficult sites

This chapter provides information on managing construction on difficult sites.

- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on designing for specific site conditions (including high groundwater, contaminated land and steep slopes) can be found in The SuDS Manual (CIRIA C753) Chapter 8.*

20.1 INTRODUCTION

'Difficult' site conditions are often seen as a reason to not use SuDS. However, this phrase is used to describe many different situations. Some challenging conditions can be resolved at the design stage, such as steeply sloping sites, or flat sites. Once resolved, these sites can be successfully constructed in the normal way if due care and attention is given to their completion. However, some site conditions require more consideration during both the design and construction phases to ensure their successful delivery. Difficult conditions for construction are mainly high groundwater, contaminated land and landfill sites.

20.2 HIGH GROUNDWATER

Shallow SuDS components such as pervious pavements or basins are an ideal surface water management solution for many sites with high groundwater. This is because they can be designed to be located above the water table avoiding the need to de-water deep trench excavations to install deep drainage. Designers should avoid SuDS below the groundwater table. However, where SuDS need to be constructed in this way, care needs to be taken during construction to manage water flows into the excavation (see **Part G Case study 37.2**).

1

Getting it right

Control groundwater during construction by appropriate dewatering.

Dewatering involves controlling groundwater so that it does not flow into excavations in an uncontrolled manner (commonly using pumping from sumps in the base of an excavation more comprehensive dewatering is a specialist area such as wellpoint dewatering).

In cases where groundwater flows will be high and will cause instability of the sides and bottom of the excavation, it may be necessary to lower groundwater levels before excavation. This is sometimes known as 'pre-drainage'. An example is wellpoint dewatering.

What can go wrong

Inadequate dewatering provisions can cause difficulties or prevent construction, which lead to delays. Examples include water seepage causing erosion or instability of slopes where groundwater emerges onto the slope surface.

Excessive dewatering can cause a reduction in the water table level that adversely affects nearby trees or structures (eg due to subsidence).



Wellpoint dewatering an excavation to allow construction of an attenuation tank

2

Getting it right

If groundwater is flowing into the SuDS check with the designer whether remedial measures or changes to the design are required.

What can go wrong

If the groundwater level is higher than the designer has assumed, the SuDS may not operate as intended or pollution of groundwater could occur. Sealed attenuation tanks could suffer from uplift forces and rise out of the ground.

The groundwater could make it difficult to form the base or sides of the excavation.



High groundwater that has not been controlled properly has made it impossible to form a stable and level base for an attenuation tank

20.3 CONTAMINATED LAND AND LANDFILL SITES

Shallow SuDS are an ideal drainage solution on many contaminated sites because they avoid the need to dig deep holes or trenches into contaminated soils. Where SuDS are constructed in contaminated soils the work should be carried out safely and contaminated soils should be managed correctly. The construction of the SuDS should not adversely affect the remediation works and the SuDS construction should not pose risks to groundwater.

A producer of waste (which includes contaminated soils) has the responsibility to:

- classify the waste
- separate and store hazardous waste safely
- arrange for authorised businesses to collect, recycle or dispose of hazardous waste
- complete a consignment note for the waste
- keep the records for three years at the premises that produces or stored the waste.

1

Getting it right

Arrange safe excavation and disposal of contaminated soils in accordance with waste management legislation.

What can go wrong

Incorrect disposal to the wrong landfill site can result in prosecution, fines and/or imprisonment in the worst cases.

Placing contaminated soils in clean areas spreads the toxic materials and results in clean-up costs.



Excavation of SuDS basin in contaminated soils with geotextile separator and clean subsoil being placed

2

Getting it right

Make sure that excavation for SuDS is not digging through any capping layer provided to stop people coming into contact with contaminated soils.

What can go wrong

Capping layer is damaged by SuDS excavation and requires repair.



Excavating through a capping layer into contaminated waste

3

Getting it right

Take appropriate health and safety precautions with respect to contaminated soils, groundwater, gas or vapours.

What can go wrong

Adverse health issues or, in worst case scenarios, the death of site operatives.



Appropriate health and safety precautions required

4

Getting it right

Ensure that pipes/large tanks do not provide a pathway for gas or vapour migration along them from one part of a site to another. Provide seals in trench backfill as shown on design drawings.

What can go wrong

Landfill gas can migrate along the permeable backfill to pipes and tanks.



Seals in trench backfill provided to pipes in contaminated land

5

Getting it right

If there are changes to the remediation works on site consult the SuDS designer to make sure that the changes do not have an adverse effect on the SuDS.

What can go wrong

Changes to remediation works can have an effect on the SuDS and stop them working as intended. They can also expose people to contamination or cause pollution.



Changes to the design of the remediation scheme required a gas ventilation layer below the geomembrane liner of some basins

CASE STUDY 20.1

Safety in excavations on contaminated sites

The drainage design for a development on a backfilled open cast mine required the installation of pipes in deep trenches. The backfill contained ground gas (carbon dioxide) that was coming from the fill and/or old mine workings below it. A worker was laying pipes in a deep trench and was overcome by carbon dioxide that had accumulated in the bottom of the trench. Efforts to save him failed and he died. The design of the drainage system should have avoided the need to enter deep trenches (ie remove the risk as required by the CDM Regulations (CDM 2015). If the risk could not have been avoided then calibrated atmospheric monitoring equipment should have been used as a minimum to warn of an unsafe environment in the deep trench.

Lessons learnt

- Ensure that appropriate health and safety measures are in place and enforced at all times.
- CDM 2015 risk assessments to avoid hazards where possible and correct remedial action taken to mitigate against identified residual risks.

20.4 STEEP SLOPES

The main concern with constructing SuDS on steep slopes is managing the speed that water flows along the system. However, this is primarily a design issue. Designers normally use check dams along swales and other components to slow water down. It is important that these measures are installed as soon as possible to prevent erosion during construction.

1

Getting it right

Ensure check dams are provided as shown on the design drawings. They should be installed before water enters the system.

What can go wrong

Insufficient or inadequate check dams can lead to erosion or loss of storage.



Stepped check dams on sloping site

CASE STUDY 20.2

Considering the design of SuDS and remediation together



Figure 20.1 Extensive excavation of polluted chalk before installing the main drainage swale in its place

On a residential site, previously occupied by a factory, it was found that a large solvent tank had been leaking into the chalk for decades. The seepage had polluted large quantities of material underground that required remediation before development could proceed.

The remediation solution was to excavate and remove the polluted chalk. Instead of backfilling the resultant excavation, it was used as a main drainage swale. However, this was only done after consultation with a specialist geo-environmental team advising on gradients, seeding, paths, outfall, covers etc to ensure that risks to health or the environment were resolved.

Lessons learnt

- Seek appropriate advice and ensure all polluted materials are removed before installing SuDS as they can provide a route for the migration of pollutants.



21 SOILS

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21.1 Introduction 111
21.2 Challenges when dealing with soils 112
21.3 Good practice checklist 114

Chapter 21

Soils

This chapter provides information on how to avoid the challenges that may arise when mixing, laying and installing soils.

- *Detailed guidance on looking after site soils is provided in Part D Chapter 11, soils for bioretention systems in Part F Chapter 31, and for trees in Part F Chapter 32.*
- *A construction checklist for soils is provided in Section 21.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on soils can be found in The SuDS Manual (CIRIA C753) Section 30.4.*

21.1 INTRODUCTION

The right soil in the right place

The question of 'what is the right soil?' is not normally considered on construction sites, as soil used is either what is already available on site, or imported material to BS 3882:2015, with 'multi-purpose grade' mainly specified. However, soils required for SuDS are widely variable depending on the function they are required to perform, eg structural support, filtration, infiltration, vegetation establishment (see **Table 21.1**).

Not all of these contain 'natural' soil and some can be 'made' on site. Understanding the purpose of each is important to ensure that the correct material is used in the right place so the SuDS will function properly. Understanding how to handle soils to maintain them in good condition and when they need protection on site is equally important.

The types of soil and their use

The range of soil types used in SuDS relates to the purpose for which they are going to be used. Those that have a particular function in SuDS, such as engineered soils that should be free-draining, should not be substituted for a different type of soil. It is important to understand how and why each soil type is made and used (see **Table 21.1**).

Making soils on site

Where large quantities of engineered soil or bioretention filter soils are required, they may need to be produced off-site. Smaller quantities can be site-mixed, but they require the correct materials supply, and control of batches as mixed. Skeleton stone soils are always constructed on site, as the stone should be compacted to the density required, before the topsoil is washed into the voids. All site-mixed soils require careful and accurate handling to ensure compliance with the specification and consistency of mix.

TABLE 21.1 Types of soil and where they are used for SuDS

Type of soil	Where used	Properties required	Soil mix contents
Natural soils	General planting areas within SuDS schemes. In the base of SuDS where additional drainage is not required.	Good quality natural soil as found on site or locally. Enhanced by fertilisers if specified after soil nutrient testing.	As found or (if supplied) to BS 3882:2015.
Specialist soils	Usually only for planting areas where specific plant species are required. Used generally and as part of an ecological enhancement area, which may include SuDS.	Unusually high or low pH as specified. These are normally low fertility soils.	Natural soils enhanced as required to BS 3882:2015.
Manufactured soils	To replace natural soils where they are unavailable. Better used within general planting areas than the SuDS unless a high quality can be guaranteed.	Good quality soil. Status of composted elements and fertiliser status requires confirmation, plus consistency of the mix.	May be made from a variety of recycled aggregates, plus compost and fertilisers. Manufactured to BS 3882:2105.
Bioretention soils/ filter media	Bioretention components including rain gardens.	A type of engineered soil. Water should be able to drain through easily, but likely to have higher topsoil and compost proportions.	Sand, topsoil and compost.
Structural soils	Beneath paving, particularly for SuDS tree pits.	Stone/rock that can be compacted to take the weight loading required, but with voids to be part filled with soil/fertilisers, and partly used to store water.	Layers of small and large stone/aggregate with natural soil brushed in between aggregates.
Engineered soils	In basins, filter strips or swales where designed as infiltration systems or to avoid waterlogging.	Water must drain through easily, and mix should have sufficient organic content to support plants/grass.	Sand based, with topsoil and compost.

21.2 CHALLENGES WHEN DEALING WITH SOILS

Most of the challenges relate to maintaining the quality of the product once delivered to prevent contamination from other materials before, during and after laying, which may change their ability to drain and/or inhibit plant growth.



Figure 21.1 Typical manufactured soil

1

Getting it right

Check that soil analysis of supply is in accordance with the specification.

What can go wrong

May not have sufficient water holding capacity, or drain properly. It may not support plant growth sufficiently.

2

Getting it right

Where several soil types are delivered, make sure that each is clearly identified, labelled/tagged and stored separately to avoid misuse.

What can go wrong

Incorrect soil may be used, that does not fulfil the properties required by the SuDS.

3

Getting it right

Prevent contamination of soil from site pollution (washing from cement supplies/mixer or other chemical agents).

What can go wrong

Potential to kill plants or severely damage their growth.

4

Getting it right

Ensure existing soil stored in heaps is protected, handled and managed.

What can go wrong

May become weed infested, which leads to new planting beds/pits being infested. This can cause problems when establishing planting or grass.

Soil structure can be damaged by waterlogging, and then slow plant growth or reduce its drainage capacity.

5

Getting it right

Ensure delivered soil is protected from heavy rainfall.

What can go wrong

May wash out sand particles from top layers of storage heap, and change its drainage properties.

6

Getting it right

Ensure site-mixed soil is consistent and in accordance with specification.

What can go wrong

May not have sufficient water capacity, or drain properly or may not support plant growth sufficiently.



Waterlogged soil in tree pit can lead to plant failure

21.3 GOOD PRACTICE CHECKLIST

See **CIRIA C753 Appendix B6** for general information on construction checklists.

TABLE 21.2 Soils checklist

	✓
Certified analysis of soil as delivered against specification	
If analysis of site soil is required, take several samples from different areas of the site	
Each type of delivered soil is separately identified to avoid misuse	
Existing soil heaps are being managed and protected in good condition	
Delivered soils are managed/handled correctly in good condition	
Batch procedure to ensure that site-mixed soil proportions and extent of mixing is correct	

CASE STUDY 21.1 Effect of compacted soil



Figure 21.2 Failed grass within residential development

A number of lawns failed to cultivate on a housing site. Site investigations revealed 100 mm of good quality topsoil, but with overly compacted sub-soil beneath. This caused poor permeability of the soil and anaerobic conditions developed in the root zone. This resulted in failure of the grass.

Remedial action required the stripping of topsoil, de-compaction of sub-soil, and then re-laying of the turf.

Lessons learnt

- When planning more consideration of sub-soil conditions and compaction will reduce issues of poor permeability, flooding and vegetation failure.

CASE STUDY 21.2

Excessive topsoil and mulch



Figure 21.3 Anaerobic soil conditions within layer of topsoil

Planting was failing within a landscape scheme and investigations were undertaken to discover the cause. On inspection of the topsoil, it was found that 500 mm depth of topsoil had been used, with 100 mm of bark mulch on top. Excessive consolidation of topsoil had occurred that, combined with the thick layer of mulch, was preventing oxygen entering the topsoil. Anaerobic soil conditions developed.

The remediation action was to strip the mulch and topsoil, apply a fresh layer of only 300 mm depth topsoil, making up the difference with de-compacted sub-soil below, and then applying a reduced 50 mm layer of mulch on top.

Lessons learnt

- Mulch should be applied with caution, and topsoil should be allowed to settle naturally and not be compacted before planting and mulch application. Compaction of topsoil prevents oxygen and water reaching the roots, causing plant failure.

Jargon buster

- **Anaerobic soil** has little oxygen available due to compaction, flooding or waterlogging, and generally occurs in clay soils. Oxygen in soils is vital for plant roots to grow.
- **Skeleton soils** are made up of large pieces of rock or aggregate with finer soil washed into the voids between pieces of rock. They are used to provide a suitable medium for healthy tree roots.



22 MATERIALS: GEOSYNTHETICS AND AGGREGATES

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Chapter

22

Materials: geosynthetics and aggregates

This chapter explains the important factors about materials used in SuDS construction, and how to avoid problems when using them.

► *Detailed guidance on construction materials can be found in The SuDS Manual (CIRIA C753) Chapter 30.*

22.1 INTRODUCTION

Many materials used in SuDS are commonly used throughout the construction industry. This section looks at construction issues that can arise when these materials are specifically used in SuDS. Geosynthetics include geomembranes (impermeable synthetic liner or barrier), geotextiles (permeable fabrics), drainage geocomposites (combination of geotextile and void-forming layer) and geocellular confinement used to stabilise permeable paving or provide tree root protection over tree pits. In SuDS construction, normal aggregates used in construction may be replaced with other materials, eg the sub-base below a pervious surface generally has different properties to that below a normal road surface.

For all materials used in SuDS design, the designer should have specified minimum and/or maximum values for their appropriate performance-related properties. Consult with the designer to ensure the materials used meet these specification requirements.

22.2 CHALLENGES WITH MATERIALS USED IN SUDS

Most challenges relate to ensuring that the specified materials are used in the correct place, and that substitutions are not made without fully understanding why the original product or material was specified. It is important to ensure that substitution will provide the same performance/properties.

Geosynthetics

The main challenges relate to ensuring that materials with the specified properties are used in the correct place and installed correctly.

1

Getting it right

Ensure that the specified materials are understood by the contractor.

Check that geomembranes, geotextiles, geocomposites and geocellular confinement materials are used in the location shown on the design drawings.



Geomembrane (waterproof sheet – normally rubber or plastic) used to hold water in



Geotextile – permeable (ie water will flow through it). This allows water to pass through geotextile and during heavy rain shows no ponding

What can go wrong

Using the wrong type of material can cause flooding or water to soak into the ground where it is not intended.



Geocellular confinement web structure holds pockets of aggregate



Geocomposite forms a drainage layer

2

Getting it right

Ensure the geomembrane is installed up the side of the SuDS component to the specified level on the design drawings to prevent water overtopping and soaking into the ground.

What can go wrong

If the membrane does not come up the sides far enough it will not provide enough storage capacity. It could also lead to unwanted or unsafe seepages that may affect building foundations or adjacent road construction.



Geomembrane – lined up with the inside edge of a bioretention planter

3

Getting it right

Geomembrane installation is a specialist skill. Operatives should be experienced and hold an appropriate National Vocational Qualification or other qualification for membrane installation.

What can go wrong

One of the main causes of defects in geomembranes is poor installation by untrained staff.



Geomembrane with limited elasticity was fitted too tight leading to a large tear

4

Getting it right

Ensure that all joints to geomembranes are welded and have been tested to confirm they are not leaking. Welded joints are more robust than taped joints.

What can go wrong

Most material suppliers do not approve the use of taped joints where the joint has to resist water pressure. Where sealed, gaps can occur if sheets are not properly flattened and aligned.



Poorly-welded joint, with geomembrane gathering creating gap in seal

5

Getting it right

Pipe penetrations through geomembranes should be sealed properly with 'Top Hats'.

What can go wrong

If penetrations are not sealed or the membrane is punctured it will leak and weaken the soil below. The leakage could also adversely affect nearby structures.



Pipe penetration sealed with Top Hat

6

Getting it right

Make sure ground is suitable (ie no sharp projections) or protection is provided. Driving on top of membranes should not be allowed unless suitable protection is provided. Membranes should be protected from access by pedestrians or vehicles after they are laid.

What can go wrong

Geomembrane could be punctured and leak.



Application of sand and geotextile protection over geomembrane layer



Geomembrane damaged by being laid on top of large projection



Geomembrane layer below a green roof destroyed by heavy trafficking and inadequate protection

7

Getting it right

Ensure that protection layers for the geomembrane are as specified on the design drawing. Check manufacturers' literature and BBA certificates for details of required protection.

What can go wrong

Geomembrane could be punctured more easily and leak if wrong protection is used.



Protective layer wrapped around geomembrane before backfilling

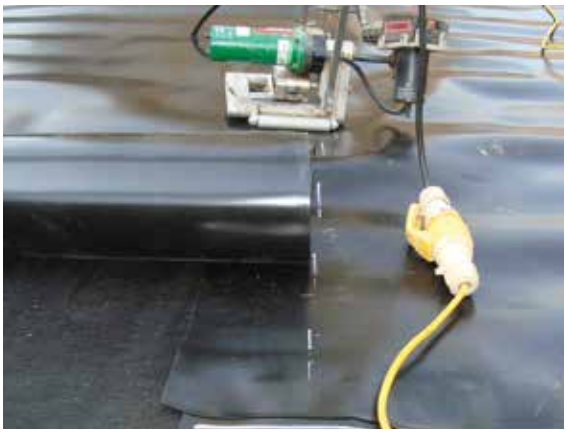
8

Getting it right

Ensure sufficient overlap between sheets of geotextile or geomembrane is provided.

What can go wrong

Overlap is normally specified by the designer. If not available refer to supplier's instructions or BBA certificate.



Overlap of geomembrane

9

Getting it right

Do not change materials used on either side of a geotextile without reference to the designer.

What can go wrong

The materials should be specified to be compatible with the geotextile and using different ones could cause the fabric to become clogged.

10

Getting it right

Make sure that geocomposites are as specified by the designer.

What can go wrong

Geocomposites that look similar may have different flow rates and if the flow rate is lower than assumed in the design flooding could occur.

11

Getting it right

Make sure that the geocellular confinement system is as specified by the designer. Some products have perforated cells walls and others are solid plastic.

What can go wrong

If the cell walls are not perforated the material can reduce or stop water flow through an aggregate layer.



Perforated wall cellular confinement product (also properly expanded)

12

Getting it right

Stretch out the geocellular confinement fully before filling.

What can go wrong

Un-expanded systems do not provide sufficient strength and the pavement will fail.



Cellular confinement has not been fully extended before filling

13

Getting it right

Provide protective layer of aggregate over the top of cellular systems before trafficking.

What can go wrong

Without a protective layer the walls of the system can be damaged and lead to structural failure.



Vehicle access onto cellular confinement web progresses as the geocells are filled

Aggregates

Challenges arise in ensuring aggregates have the specified properties and are laid correctly.

1

Getting it right

The main aggregates that are used in SuDS are designed to store and allow the flow of water.

The designer should have specified the porosity (a measure of how much void space there is) and permeability (a measure of how fast water can flow) of the materials.

What can go wrong

Using the wrong materials may result in them not being permeable enough or not providing enough storage. This will cause ponding or flooding. The membrane could be punctured and leak if an aggregate is overly sharp.



Aggregate laid within bio-retention planter as per specification to allow for good infiltration

22.3 GOOD PRACTICE CHECKLIST

This list should be used as a basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 22.1 Materials: geosynthetics and aggregates checklist ✓

Materials delivered to site conform to specification	
If on-site sampling or testing is required, take several samples from different parts of the site	
Supplier's requirements for storage, handling and installation are followed	
Requirements on certificates (eg BBA) for storage, handling and installation are followed	
Qualifications or experience of geomembrane installers	

CASE STUDY 22.1 Design of geomembrane and its effect on construction

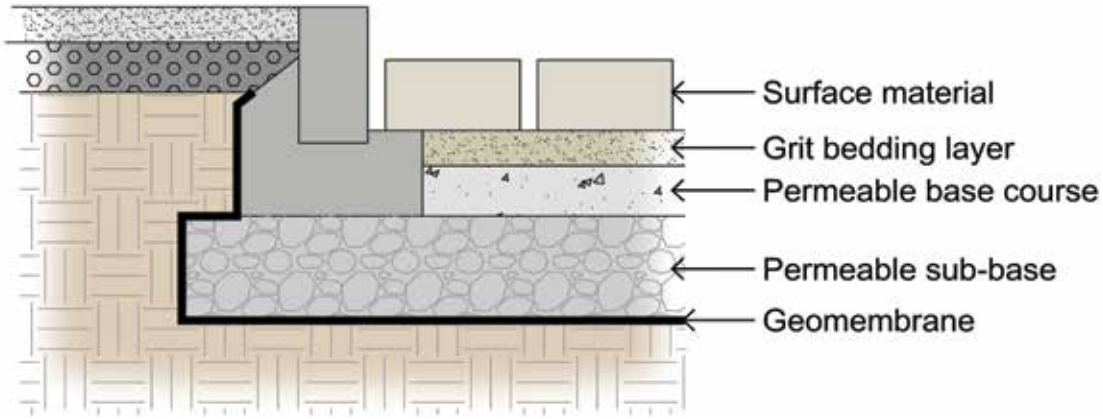


Figure 22.1 Geomembrane detail wrapping around outside of the kerb

A road was to be constructed as permeable block paving with a geomembrane around the sub-base. The design showed the geomembrane within the concrete haunching to the kerbs that, given the thin amount of concrete at this point, would have cracked. Another challenge with this detail is that if it is not installed and set out accurately from the start, a lot of remedial work could then be required to make it look tidy. This becomes more difficult after the permeable sub-base is installed on top of the geomembrane, kerb race installed and the excavation backfilled, as it is not easy to move or work on the membrane without undermining the kerb.

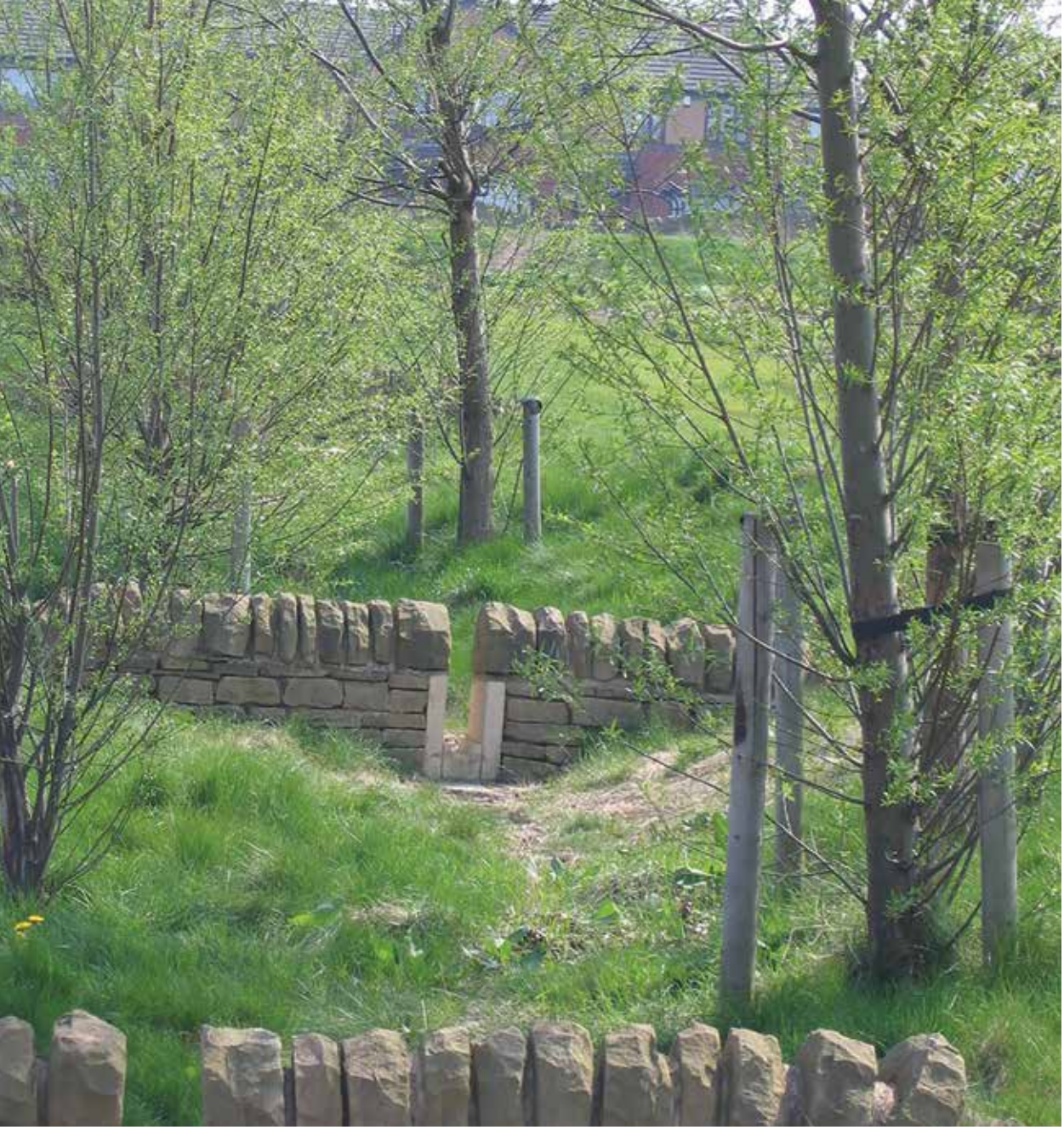
The contractor agreed with the client to revert to a detail that had been used successfully before, where the geomembrane ran on the outside of the kerb. This removed the problem. Later in the project the geomembrane had to be moved so that services could be laid under the footpaths. This could have been avoided with better setting out, or having the membrane on the inside of the kerb. The only solution to the problem was to remove the backfill in small sections, remove some of the permeable sub-base, and then lift the membrane and backfill. This was slow and expensive to correct. It also significantly increased the risk of damage and leaks in the geomembrane.

Lessons learnt

- Due to the difficulties encountered on this project, the client decided to review their typical details for geomembrane installation.

Jargon buster

- A **British Board of Agrément (BBA) Certificate** is a document that shows the fitness for the purpose of a construction product and its compliance or contribution to compliance with the various Building Regulations applying in the UK. BBA certificates are awarded to products that have passed a comprehensive assessment that includes laboratory testing, an onsite evaluation and production inspection. The certificates contain details of the physical properties, limits on application and installation procedures that must be followed.
- A **component** is a drainage feature that can take many different forms.
- **Geomembranes** are impermeable sheets. Typically polymer sheets of polypropylene (PP) or low or high density polyethylene or rubber.
- **Geotextiles** (commonly known as Terram(R)) are permeable and allow water to pass through while retaining soil particles.
- **Geocomposites** are drainage layers. Although in some types a cuspated sheet that forms the drainage layer may be hard and impermeable it is often not practical to weld the sheets together to form a waterproof system.
- **Geocellular confinement** is a stabilising system that increases the stiffness of aggregate layers.
- A **Top Hat** is a pre-formed cloak that fits around a pipe or other penetration through a geomembrane. It is sealed to the membrane and the pentration to make the joint water tight.



23 INLETS, OUTLETS AND FLOW CONTROL SYSTEMS

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Chapter

23

Inlets, outlets and flow control systems

This chapter provides information on the challenges that may arise when constructing inlets, outlets or flow controls and how to avoid them.

- *A construction checklist for inlets and outlets is given in Section 23.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design of inlets, outlets and flow control systems can be found in The SuDS Manual (CIRIA C753) Chapter 28.*
- *General information on construction checklists, see The SuDS Manual (CIRIA C753) Appendix B6.*

23.1 INTRODUCTION

Inlets and outlets manage water flow into and out of SuDS components. These may comprise pipes in headwalls, as commonly used for normal drainage, but for SuDS they are often smaller-scale features that blend into the landscape. However, be aware that smaller structures may be difficult to construct correctly and can be concealed and blocked by heavy vegetation around them (see **Part G Case study 37.2**).

Outlets may also incorporate flow controls that limit how fast water is discharged. Flow controls can be small circular openings in weir walls, located inside inspection chambers or weirs, or found in more complex manufactured devices that bolt onto the side of the chamber wall. The flow controls are designed to specific dimensions and these should never be changed by those constructing the SuDS unless instructed by the designers.

Before starting construction, the design drawings should be checked to ensure that the pipe sizes in and out of chambers are complete and fully detailed and if not, consult the designer. Work should not start on the inlets and outlets until the design drawings are available.

23.2 CHALLENGES IN CONSTRUCTING INLETS AND OUTLETS

As inlets and outlets (and flow controls) are fundamental to controlling the volume and rate of water flowing into and out of a SuDS component, the levels, detailing and correct installation is particularly important if they are to fulfil the design requirements.

1

Getting it right

Pipes and flow controls must be set at the correct levels.

What can go wrong

Storage may not operate correctly if outlet levels are set incorrectly.





Traditional headwall for pipes carrying high flows and SuDS headwall with smaller pipe carrying low flows

2

Getting it right

Construction of detailed finishes must be robust, eg flush concrete, stone or other surrounds to pipes. The cut ends of plastic pipe should be not be left exposed.

What can go wrong

System performance may be affected.

Finishes may be unsightly, which can lead to complaints.



Poor detailing makes this visually unacceptable

3

Getting it right

Ensure that design drawings are double checked for details and dimensions before construction.

What can go wrong

System is unlikely to work as anticipated if the dimensions are not correct. It may fail and cause flooding of development, or excess flow from the site.



This notch in the brickwork weir should have had a steel plate built into it to control flow

4

Getting it right

If outlets become blocked during construction, make sure all obstructions are removed at the end of construction (it is vital to check all manholes and chambers).

What can go wrong

Blocked outlets will cause the system to back up and potentially flood.



A rag used to block outlet orifice during leakage test was not removed afterwards causing blockage

5

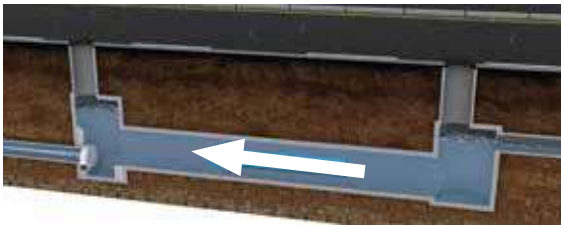
Getting it right

If changing supplier of a vortex flow control the SuDS designer should be consulted. Vortex controls may look similar, but can give widely different levels of performance.

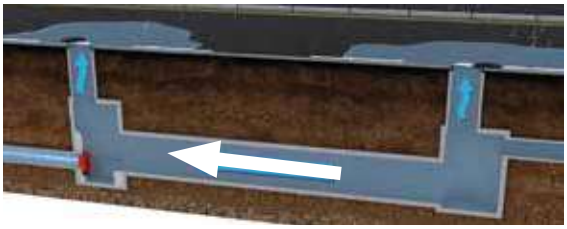
If an alternative to a flow control is supplied, the designer must confirm that it is suitable for the scheme (this may require the design to be recalculated using the flow characteristics for the alternative control).

What can go wrong

Vortex flow controls from different suppliers may allow more water out of the system for a given upstream water level than the one specified by the designer, leading to a less effective scheme and possibly flooding elsewhere.



Drainage system working as designed



Compromised performance due to different vortex flow control than specified

6

Getting it right

Make sure the control unit is fitted correctly. Some flow controls slide into the pipe outlet of a manhole and need to be slightly smaller in diameter than the pipe.

What can go wrong

Incorrect size can lead to delays on site while a new unit is ordered or the inappropriate unit may be fitted, potentially causing future blockages or flooding.



Flow control incorrectly installed on the wrong side of the weir wall. Flow control fitted to the wrong side

7

Getting it right

Make sure the flow control is constructed in the correct position in the chamber (eg they are normally designed to go on the outlet so should not be constructed over the inlet).

What can go wrong

If installed in the wrong position the flow control will not work correctly and could lead to the site flooding. For example, if a manhole has multiple inlets and the flow control is installed over one of them instead of the outlet, the system will not operate as designed.



Vortex flow control flitted to outlet from a manhole

8

Getting it right

For larger flow controls the unit needs to be installed into the manhole before the cover slab is installed.

What can go wrong

If the unit will not fit through the access hole in the cover slab, delays are caused as the slab has to be removed.



Large flow control being fitted in advance of cover slab

23.3 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 23.1 Inlets, outlets and flow control systems checklist ✓

Level of outlets and overflows are as specified on the design drawings	
Dimensions of outlets and flow controls are as specified on design drawings	
Flow control is from the supplier specified on design drawings (if appropriate). If not, the designer has confirmed their performance as acceptable	
Flow controls (eg vortex flow controls) are installed the right way up and in the position shown on design drawings (eg on the outlet pipe)	
Finishing of the details is as shown on design drawings (ie construction is visually attractive)	
The connection to sewer is via the demarcation manhole in accordance with WRc (2007)	

CASE STUDY 23.1 Impact of contractor changing flow controls without consulting the designer

A SuDS scheme relied on the co-ordinated control of flows and storage between all parts of a piped system, which included underground tanks and an infiltration basin. Someone involved in the construction decided to change the flow controls in the manholes. In most instances, instead of providing a single orifice flow control, two orifices with a diameter slightly smaller than the design were provided. This resulted in significantly greater flows being passed to the downstream storage components.

Table 23.2 As-built versus designed orifice size

As-built outgoing pipe and orifice size	Designed orifice size
2 x 240 mm plate	1 x 245 mm
2 x 160 mm plate	1 x 160 mm
1 x 150 mm plate	1 x 160 mm
2 x 210 mm plate	1 x 220 mm

A significant amount of time and money was spent in modelling and measuring flows in the system and verifying it was performing as required. This demonstrated that even with the additional flow controls the downstream storage operated as required in the design with the results that remedial works were not required. However, the remodelling exercise resulted in a long delay before the system was adopted by the sewerage undertaker.

Lessons learnt

- The original designer should be involved in changes to the SuDS as designed to ensure that it fulfils the original design criteria.

CASE STUDY 23.2

Impact of contractor's design changes



Figure 23.1 Channel collecting road surface water runoff

A SuDS scheme within a housing estate in Scotland incorporated a roadside swale into its design. However, upon completion it did not function as intended. The inlet to the swale from the road only directed sheet flow runoff from a small part of the road through a single drainage channel into the swale. The back outlet from the drainage channel into the swale was located right next to a gully in the base of the swale. The gulley was connected to a sewer. Water flowed directly into the sewer and bypassed the swale, resulting in no treatment of the water. Also, the use of an open-ended pipe to discharge the water into the swale/gully quickly caused erosion. This issue arose due to a lack of knowledge of SuDS principles or understanding of the design drawings by the contractors on site.

Lessons learnt

- Use experienced contractors with a good understanding of SuDS or work closely with the contractor to ensure they fully understand what is required.
- Thoroughly check contractor's works at all stages to ensure compliance with the design drawings.

CASE STUDY 23.3

Misinterpretation of design drawings

During the construction of a retrofitted series of inter-connected SuDS, the design drawings specified the construction of a gabion basket filled with stone as an outlet detail. However, the design drawings were misinterpreted by the contractor and as a result the outlet was constructed as a solid section of mortar jointed granite setts, which inevitably blocked the flow of water into the lower basins.

As the SuDS was unable to function, it was necessary for the contractors to remove the outlet as constructed, and re-build it according to the original design drawings as a stone filled gabion basket.

Lessons learnt

- It is vital that where the appointed contractors do not have good experience with SuDS construction, that the SuDS designer (or someone with the required understanding) is retained on the project. This will ensure that the contractor fully understands the design intent, so that components are constructed correctly and will fulfil their function.



Figure 23.2 'Outlet' blocking flow along the SuDS management train

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Infiltration** is the ability of the soil to absorb water.
- A **swale** is a SuDS component that is similar to a wide shallow ditch, but with a flat bottom.
- A **demarcation manhole or chamber** is placed at the boundary between sections of a drainage system that are in different ownership. The manhole or chamber delineates the change of ownership. This is usually required by water companies to identify the head of an adoptable lateral drain.
- A **vortex flow control** is a specialist flow control product that is designed and manufactured to achieve specific flow characteristics. The flow control causes a spiral flow of water in a chamber used to control the flow.
- An **orifice flow control** is a small hole (normally circular) that restricts the flow of water through it.

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24 RAINWATER HARVESTING

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Chapter

24

Rainwater harvesting

This chapter provides information on the challenges that may arise when collecting rainwater for use on site and how to avoid them, and particularly its collection and subsequent storage in tanks.

- *See also Part F Chapter 34 for attenuation storage tanks, and if water is to be stored in the base of pervious paving to Part F Chapter 33.*
- *A construction checklist for rainwater harvesting is provided in Section 24.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design of rainwater harvesting tanks can be found in The SuDS Manual (CIRIA C753) Chapter 14.*
- *General information on construction checklists can be found in The SuDS Manual (CIRIA C753) Appendix B6.*

24.1 INTRODUCTION

Rainwater harvesting is the collection of rainwater runoff for use on site. Water for use is normally collected from roofs (and in some instances where pollution risks are assessed to be acceptable from pervious surfaces). The water is collected either in a tank (above or below the ground), or in the sub-base below pervious surfaces where it is stored and then pumped to a tap when required. The water can be used in a number of ways where drinking water standards do not have to be met, and the risk posed by contamination is less than for drinking and bathing. Uses for harvested rainwater include watering plants, washing clothes and cars, and flushing toilets.

24.2 CHALLENGES IN CONSTRUCTING RAINWATER HARVESTING SYSTEMS

General challenges relate to levels, connections, overflows, pumps and filters, and ensuring that there is a backup mains water supply. It is also common for one contractor to install the tank and different contractors to install the pumps and internal plumbing. There is a need for good communication between all the contractors to avoid problems.

Part F Chapter 33 provides guidance if the water is stored below a pervious surface area. **Part F Chapter 34** provides information if the system has underground storage tanks. Also, detailed information on the installation of rainwater harvesting is given in BS 8515:2009+A1:2013.

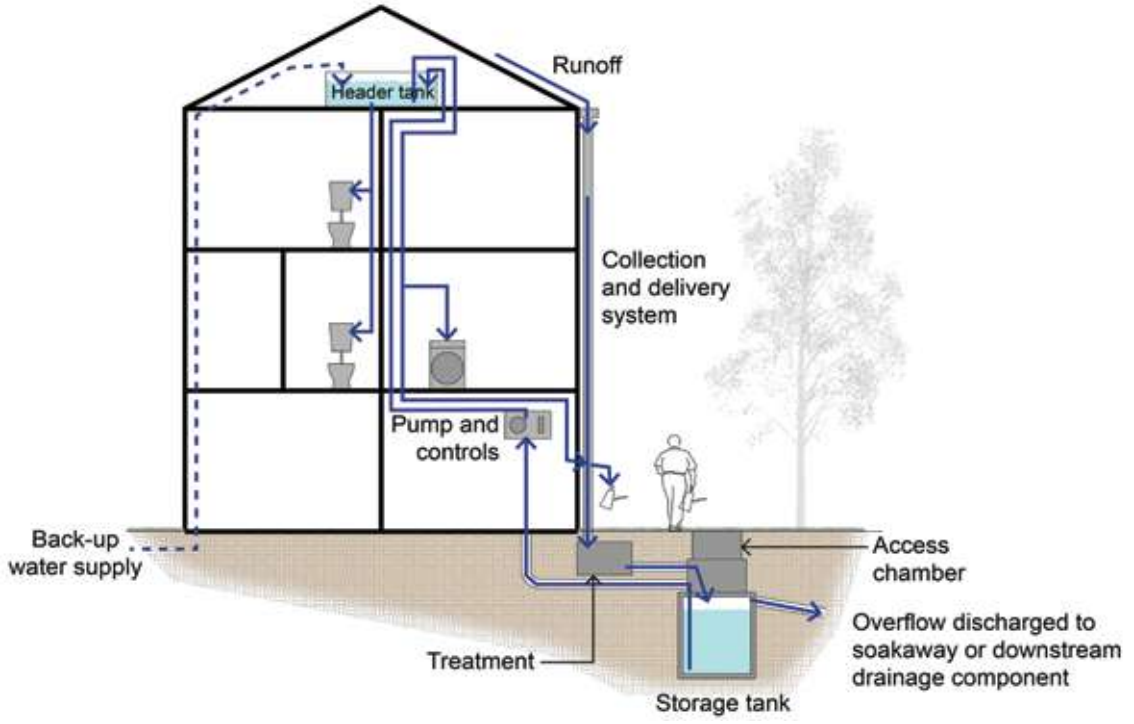


Figure 24.1 Typical parts of a pumped rainwater harvesting system

1

Getting it right

Ensure the tank is built to the correct levels.

What can go wrong

The tank does not operate as intended (flooding could occur or it may not hold sufficient water).



This rainwater harvesting tank was set too low and water backed into the tank causing the filter to lift from its seating

2

Getting it right

Ensure inflows/outfalls/overflows are built to correct levels.

What can go wrong

May not store enough water or overflow frequently enough.



Overflowing water butt – does not have appropriate overflow

3

Getting it right

Ensure all drainage areas are connected to the tank as planned in the design.

What can go wrong

If all areas are not connected, the tank will collect less water than planned. The system may run out of water or use more mains water than planned, leading to under performance of system.

4

Getting it right

If the system overflows to a drainage field or other soakaway, ensure the field is of sufficient size for the soils (check with designer if unsure).

What can go wrong

Gardens or other areas can become water logged or the system will not overflow and flooding occurs.

See **Part E Chapter 20** on infiltration systems.



Overflow within drainage field

5

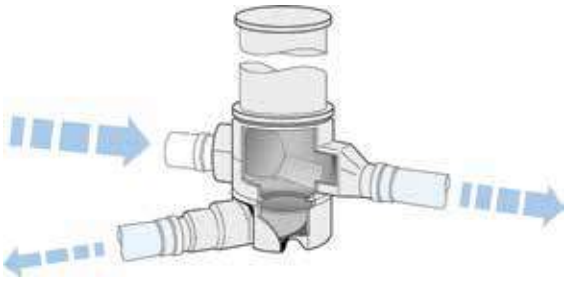
Getting it right

Ensure all filters are installed in accordance with instructions.

What can go wrong

Unfiltered water could come out of taps and may pose a health risk, or may smell and look unsightly.

Filters could block and cause flooding.



Underground rainwater filter – water going into the tank with the rest filtered to drain

6

Getting it right

Ensure pumps are installed correctly and float levels that turn pumps on and off are set to correct levels.

What can go wrong

Poor supply of harvested rainwater.



Pump

7

Getting it right

Ensure that the mains water backup is connected correctly (if required).

What can go wrong

Water may not be available when required during periods of low or no rainfall.



Connection schematic for rainwater harvesting control unit with integrated pump, mains water top-up and controls

8

Getting it right

Ensure that only pipes leading to non-potable taps or uses are connected. Double check to ensure no cross connections with main water supply. Supply information on the system to the building owner/occupier.

What can go wrong

Cross connections can cause contamination of the drinking water supply to the building.



Signage used to confirm what pipes are carrying or what drainage points are to be used for

9

Getting it right

Ensure adequate labelling of the tank and control locations is provided above the ground.

What can go wrong

Future maintenance or extensions could lead to incorrect connection of taps to the rainwater system (eg it could have taps for drinking water connected).



Warning sign indicating appliances supplied by rainwater

24.3 CHALLENGES THAT APPLY TO STORAGE TANKS

These challenges relate to ensuring the tank is properly bedded and stable. Above ground tanks should be provided with suitable foundations and supports. See **Part F Chapter 34**.

1

Getting it right

Ensure underground tank is provided with concrete, gravel or other surround and bedding as specified by supplier.

What can go wrong

Tanks could collapse if the structural design of the installation is inadequate or if the tank is installed incorrectly. The tank may float out of the ground if groundwater or floodwater is high and the tank has insufficient inherent strength, self-weight and anchorage.



Underground tanks installed with appropriate surrounding materials

2

Getting it right

Ensure above ground tanks have a firm and stable support as shown in the instructions from the supplier.

What can go wrong

Tanks could fall over and in the worst case injure or kill someone.



Above ground tank set on large purpose built concrete base

24.4 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 24.1 Rainwater harvesting checklist

	✓
Both the tank and the overflow are built to the correct level	
All areas planned to drain to the tanks are included	
Drainage field has right capacity for volume of drainage required	
All filters are installed correctly	
Underground tank has correct surround and bedding	
Above ground tank has stable supports	
There are no misconnections between SuDS and mains water supply	

CASE STUDY 24.1

Incorrect backfill

A private householder had a rainwater harvesting system installed during the construction of an extension, but the plastic tank was installed in the garden without the correct backfill specified by the supplier. Rather than use pea gravel the builder used clay excavated from the hole to backfill around the tank. The backfill used also had bricks in it. The large lumps of clay and bricks put too much pressure at local points on the tank and caused it to collapse. The tank had to be excavated and replaced.

Lessons learnt

- The backfill should be as specified by the supplier of the tank. As dug material should not be used unless approved by the tank designer.
- The tank should be protected from pressure points caused by bulky/sharp objects in the backfill.

CASE STUDY 24.2

Poor level control

A rainwater harvesting system was installed for a private householder, where the overflow pipe that led to the sewer was laid at a shallow gradient. This had a backfall on it so that it drained back into the tank. The overflow pipe also had a roof downpipe connected into it. This meant that water could flow back into the tank, despite the presence of a flap valve. The result was that water levels in the tank were rising above the design overflow level, and the inlet filter was then floating out of place and not working. A custom-built extension to the filter housing and lid was made to lift the filter into a position where it could operate correctly. The downpipe was also disconnected from the overflow and connected to the surface water drain alongside the house.

Lessons learnt

- Check all levels within the design are correct before installation to make sure connections from or to existing drainage points can be achieved with the necessary gradient.

Jargon buster

- A **drainage field** is a shallow system of perforated pipes and/or gravel-filled trenches to which the overflow from a rainwater harvesting system may be directed. The drainage field allows water to soak into the ground.



25 GREEN AND BLUE ROOFS

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Chapter

25

Green and blue roofs

This chapter provides information on the challenges that may arise when constructing green and blue roofs and how to avoid them.

- *A construction checklist for green and blue roofs is provided in Section 25.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design and construction of green roofs can be found in The SuDS Manual (CIRIA C753) Chapter 12.*

25.1 INTRODUCTION

Green roofs are rooftop drainage and waterproofing systems that are covered with vegetation, usually specific plants that are selected to survive in what is mainly quite a dry environment.



Blue roofs are rainwater attenuation systems on rooftops that may be covered with planting or with hard surfaces.

Figure 25.1 Green roofs in Nottingham



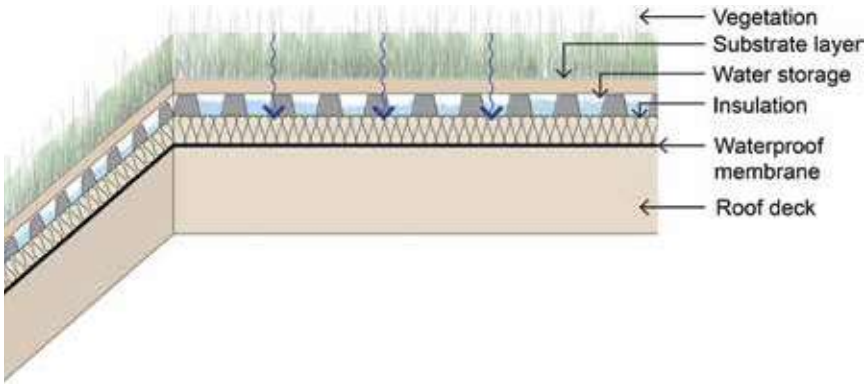


Figure 25.2 Green roof construction

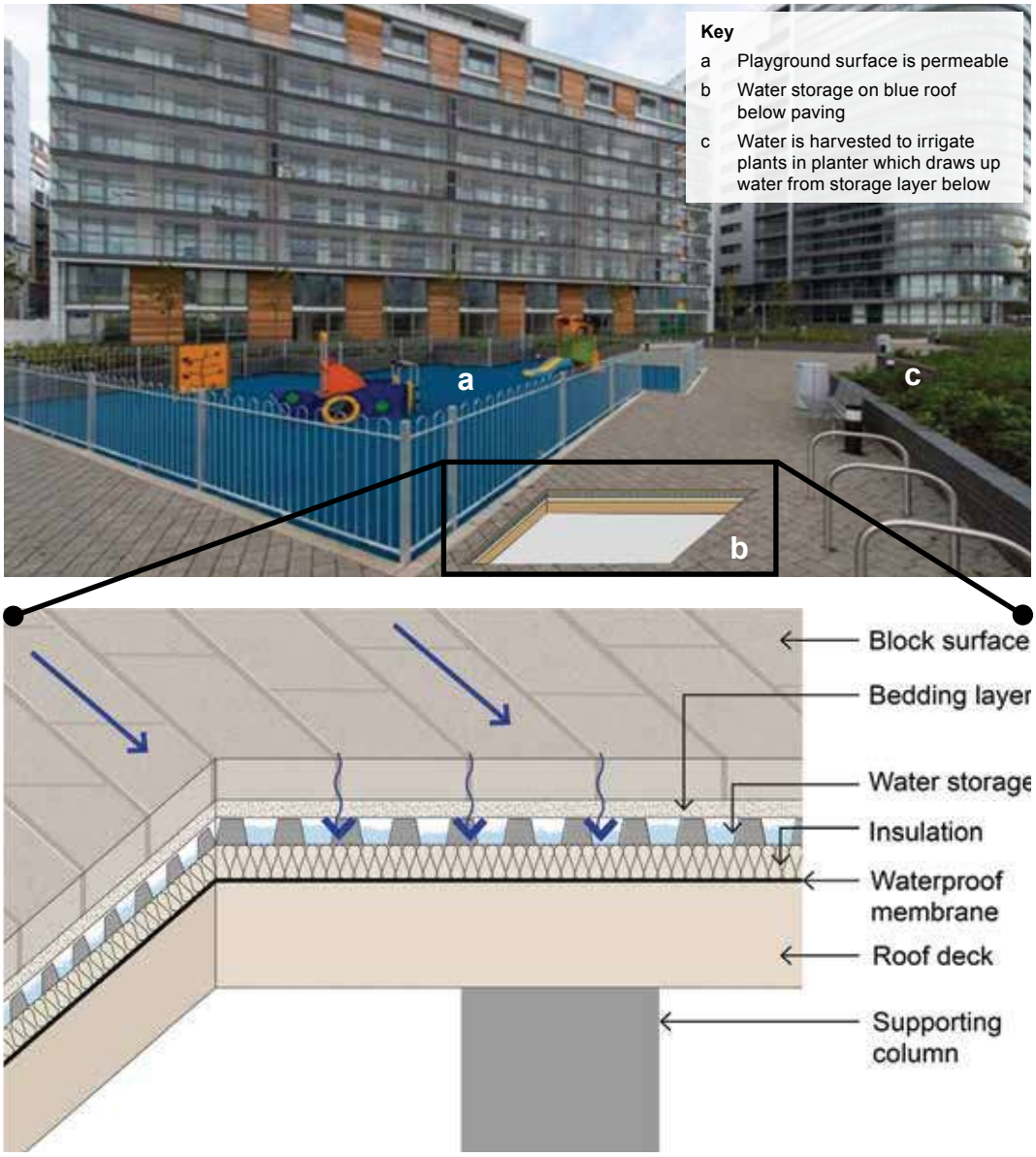


Figure 25.3 Blue roof, with cut-away showing the layering of the blue roof design

25.2 CHALLENGES WHEN CONSTRUCTING GREEN AND BLUE ROOFS

Issues that arise when constructing these roof types generally relate to setting the correct levels and falls to ensure the roof will store both the amount of water required and drain adequately. Installing the correct waterproofing to ensure that the structure is watertight is also important for all roofs. The membrane should be sufficiently protected from damage by the materials or planting above it. Quality installation of the waterproofing layer is essential to avoid leaks into the building.

1

Getting it right

Ensure levels are correct and have adequate falls towards outfalls.

What can go wrong

Water may pond along the length of the roof and not drain. Water ingress under flashings can occur.



Water does not drain to outfall due to incorrect levels

2

Getting it right

Ensure correct levels to outfalls.

What can go wrong

May not store enough water or too much water.



Gradients to outfall along roof edge

3

Getting it right

Ensure that the construction depths are correct.

What can go wrong

System is unlikely to work as anticipated and may fail.

Substrate may be thinner in the centre of the roof than at edges.

Plants may die and retention of water will be reduced.

Thicker layers may introduce additional loading to the roof and cause structural problems.



Green roof laid to correct substrate depths

4

Getting it right

Ensure that the correct/specified materials are used for the proposed drainage and planting design.

What can go wrong

System unlikely to work as anticipated and may fail leading to greater water flows from roof and/or standing water on roof.

Plants may die.

Biodiversity objectives may not be met.



Different substrate materials being placed on a roof to meet biodiversity requirements

5

Getting it right

Ensure drainage boards (where specified) are laid the correct way up. Make sure drainage boards are laid across roof surface and as shown in the design.

What can go wrong

Water will find it hard to enter the drainage layer and ponding of surface water will occur if drainage board is not the right way up.



Drainage layer being laid correctly

6

Getting it right

Protection layers to the waterproofing membrane should be provided as specified in the design.

What can go wrong

Roof may puncture and leak.



Protective layer on top of a waterproof membrane

7

Getting it right

Provide the correct number, size, location and specification of drainage outlets as shown on the design drawings.

What can go wrong

Blue and green roofs can have different types of outlet that perform in significantly different ways.

Use of an alternative outlet to the one designed may result in too much or too little water leaving the roof.

May cause flooding of the roof.



Retrofitted green roof uses existing drainage outlets that were checked for correct sizing

25.3 CHALLENGES THAT ONLY APPLY TO GREEN ROOFS

Green roofs often have a combination of proprietary systems and bespoke design elements, so using properly qualified installers will reduce the potential for problems in construction. The depths of the substrate and plant/seed mix are designed to work together so neither can be changed without understanding how it may affect the other. Guidance may be needed from the original designer.

1

Getting it right

Use qualified/experienced installers who follow the guidance by the GRO (2014).

What can go wrong

Inexperienced installers are more likely to make mistakes leading to poor performance and poor quality roofs.



Green roof installation by qualified installers

2

Getting it right

Plants and seeds should be used as specified in the design with the correct planting density or spreading rate or use sedum mat as specified in the design.

Ensure depths of substrates are consistent with the design drawings and specification.

What can go wrong

Planting may fail or the balance of the planting mix may not work with one species dominating the others.

Plants may die if insufficient or incorrect substrate is used.



Sedum roof failure due to planting with incorrect species

25.4 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 25.1 Green and blue roofs checklist ✓

Roof/insulation surface is clean and free of sharp protrusions that could puncture the membrane	
Roof membrane is installed as per design details and verified/tested by appropriate person as specified	
Protection layer/root barrier placed over membrane if required	
Drainage layer installed across whole of design area (do not just check at edges)	
Drainage layer is the same product as specified on design drawings and is installed the right way up	
Drainage layer connected to outlets	
Correct number, size, specification and location of drainage outlets	
Growing media as specified in design both for content and laying depths	
Growing media/substrate is correct thickness across the whole area (not just the edges)	
Mounds introduced for biodiversity or other purposes are as shown on design drawings	
Plants/seeds as specified on design drawing and at correct density, or that sedum mat is the correct thickness	
Biodiversity features are installed (eg old tree branches or logs)	
Edge drainage, border zones and fire breaks installed as per design	
An appropriate watering regime is in place to ensure the successful establishment of the plants/ seeding/sedum mat	
Ensure monitoring regime for plants is in place (to inform early decisions on performance and maintenance, and allow for the possible introduction of additional species as the roof establishes)	

CASE STUDY 25.1

Changing the specification of a flow control

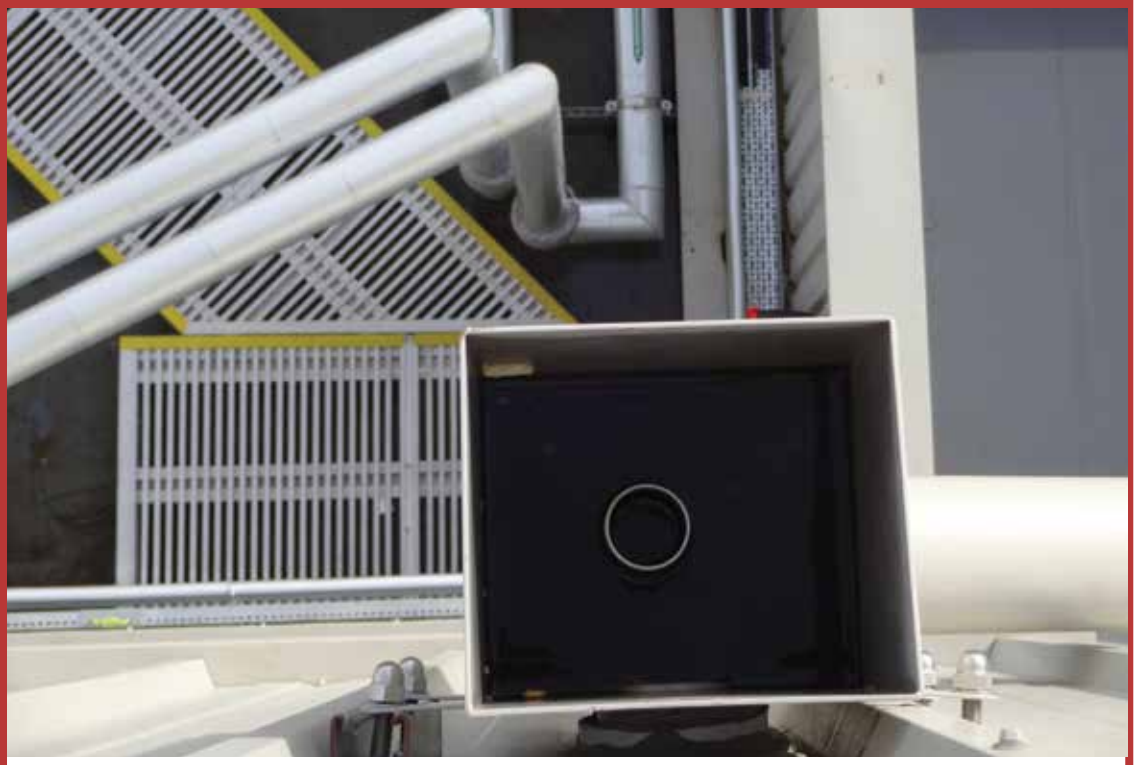


Figure 25.11 Vortex flow control fitted, slowing outlet of water from blue roof and increasing duration of water retention

A commercial building was designed with over-sized guttering to allow for water storage on the roof, but no flow controls were installed on the downpipes from the roof. This resulted in water leaving the roof too quickly, providing limited water storage capacity. The drainage system at ground level was too small to cope with the amount of water coming off the roof and flooding occurred.

Vortex flow controls were installed within the gutters, restricting the flow into the downpipes to the designed limit. The rainwater was held on the roof for longer and drained more slowly to the ground level system alleviating ground level flooding.

Lessons learnt

- Ensure flow controls are in place to maximise water retention capacity and reduce flooding risk further down the system.

Jargon buster

- A **vortex flow control** is a specialist flow control product that is designed and manufactured to achieve specific flow characteristics. The flow control causes a spiral flow of water in a chamber used to control the flow.



26 INFILTRATION SYSTEMS

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Chapter
26

Infiltration systems

This chapter provides information on the challenges that may arise when constructing infiltration systems and how to avoid them.

- *A construction checklist for infiltration systems is provided in Section 26.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design of infiltration systems can be found in The SuDS Manual (CIRIA C753) Chapter 13.*
- *General information on construction checklists can be found in The SuDS Manual (CIRIA C753) Appendix B6.*

26.1 INTRODUCTION

Infiltration systems allow runoff to soak into the ground where the ground is suitably permeable, rather than letting water flow to a surface water drain or stream/river. Infiltration can be provided by soakaways, infiltration trenches and basins, or from the sub-base of swales or permeable pavements. Normally the rate of infiltration to the ground is slower than the rate of water flowing into the infiltration system. So, a storage volume or space is provided either in the soakaway chamber, the basin, the pore spaces of trench infill, or in the permeable sub-base.

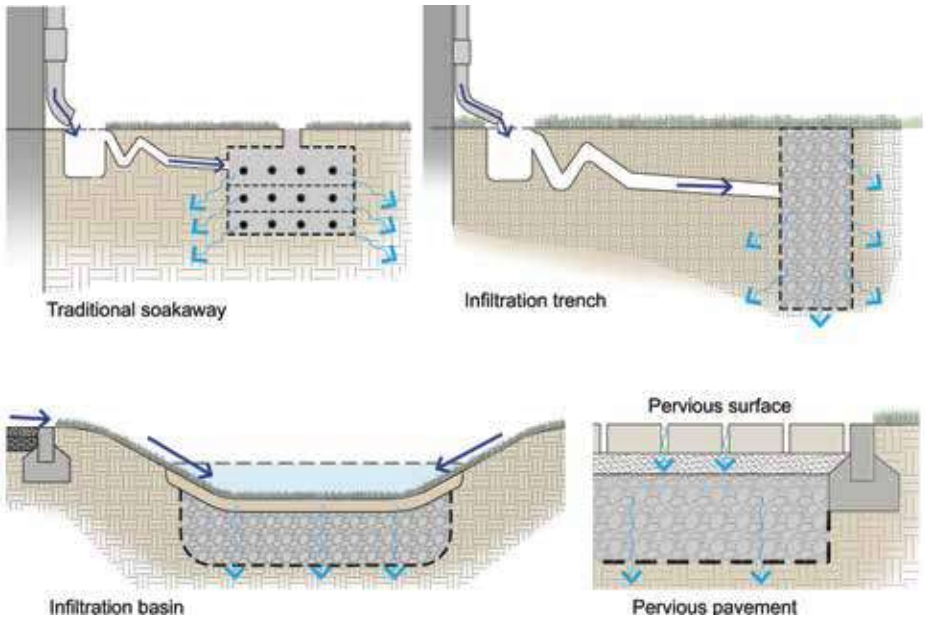


Figure 26.1 Infiltration systems

The natural (pre-construction) permeability of soils around infiltration components should be established during the design stage. It is important that construction activities do not clog the ground below the infiltration system or compact it so that water does not filter through it as fast as was assumed in the design. The infiltration test results should have been obtained at the start of the contract, and the infiltration rates for the finished component should be tested as part of inspection procedures. For details on baseline information see **Part B Chapter 3**.

26.2 CHALLENGES WHEN CONSTRUCTING INFILTRATION SYSTEMS

There are many challenges that can arise, including constructing incorrect levels, not using specified materials and the compaction of soils, which can prevent water soaking into the ground.

1

Getting it right

Make sure the works are constructed to the correct levels.

What can go wrong

Water may pond and not drain effectively.



Levels constructed incorrectly and soil not infiltrating through the bioretention system

2

Getting it right

Ensure correct levels are constructed to inlets.

What can go wrong

System may not store enough water.



Weirs set to correct levels

3

Getting it right

Use correctly specified backfill materials with the right grading.

What can go wrong

System unlikely to work as anticipated and may collapse (incorrect backfill can put too much pressure on sides) or flooding may occur (not enough water storage or water cannot flow out fast enough).



Single size infill or backfill to infiltration trench has a high permeability and large void space to store water

4

Getting it right

Ensure areas that are designed to allow water to soak into the ground (basins, pervious surfaces) are not compacted.

What can go wrong

Compaction reduces infiltration, the rate that water soaks into the ground, and will reduce the system's performance. This may cause ponding on the surface or flooding further down the system.



Compaction of formation by site plant will reduce infiltration

5

Getting it right

Muddy water or fine material should be prevented from flowing into the infiltration system.

What can go wrong

Muddy water will clog soil and/or backfill, so the water cannot flow out quickly enough causing surface flooding/ponding.



Muddy water flowing into infiltration basin causing clogging of surface

26.3 SOAKAWAYS AND INFILTRATION TRENCHES

These components require water to infiltrate to deeper ground levels through a feature that is constructed vertically.

1

Getting it right

Ensure soakaways and infiltration trenches are constructed to the depths or levels as shown on design drawings.

What can go wrong

If excavations are not deep enough the system may not reach the permeable layers into which water should flow. This will prevent effective drainage.



Excavation to reach permeable layer at base

26.4 PERVIOUS PAVEMENTS

Issues that can arise from either the sub-base or finished surface becoming clogged with fine site material or muddy site water.

1

Getting it right

Avoid storing materials (and particularly loose and/or fine materials) on the permeable area where they could clog the surface.

What can go wrong

Fine sands, cement, topsoil or bark mulch could all clog the infiltration or pervious surface preventing effective drainage.



Clogging of pervious surface where inappropriate material has been stored

2

Getting it right

Ensure that the pervious surfaces are protected so that muddy water, soils or mulch does not flow on top of them.

What can go wrong

Muddy water or fines within mulches can clog the finished pervious surfaces and their sub-bases.



Mulch washing into the pervious system

26.5 INFILTRATION SWALES AND BASINS

Challenges that can arise include maintaining permeability of the soils and underlying infiltration layers during construction.

1

Getting it right

Make sure the correct topsoil is used (ie it should be sandy material with permeability as defined in the specification).

What can go wrong

Too great a clay or silt content will cause water to pond on the surface and prevent infiltration into the ground.



Effect of using topsoil with too much clay/silt content causes water to pond on the surface of an infiltration basin



Watch point

It is vital to protect the ground where infiltration is assumed so that infiltration rates are not slowed by compaction or blinding by silt.

26.6 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 26.1 Infiltration systems checklist ✓

Excavations are to the correct design levels	
Sides and base of excavation to expose soils and check against soil type assumed in the design	
The base is level and suitable for construction of the soakaway tank or basin	
The area for infiltration has not been compacted. If so, rectify and re-inspect	
Soakaway units are as specified on the design drawings	
Backfill is as specified and compacted sufficiently with machinery that is not too heavy	
Basin topsoil is as specified and sufficiently permeable	
Basin planting is as specified – species, size and density	
Muddy runoff – ensure that dirt has not been allowed to enter the system. If it has, then ensure that it has been cleaned out to an acceptable standard	
The specified depth of soil in the design drawings has been placed over the top of the soakaway tank	

CASE STUDY 26.1

Incorrect drainage levels and the effect on infiltration performance

A shared soakaway was constructed to drain several houses. Immediately after construction was completed it became apparent that it was not draining effectively, with regular flooding of the shared access and gardens.

The soakaway was constructed using geocellular units, but without detailed design drawings showing how the inlet pipes should be connected, or what the maximum depth of backfill was required. Investigations into the cause of the flooding were compromised by a lack of as-built construction drawings showing the precise location and dimensions of the constructed soakaway (which were found to be different from those shown on design drawings that were available).

The construction of the inlet to the soakaway comprised a solid pipe with an open end that allowed water to drain into gravel on the top of the tank, but rapidly clogged up with leaves. (A perforated pipe of sufficient length and perforation area should have been used rather than relying on water flowing into the gravel from the small area at the end of the pipe.)

There was no means of access to the soakaway to inspect it for clogging or water levels, which made it difficult to assess its operation.

The local geology was complex with an impermeable layer of clay above mudstone bedrock. The mudstone was more permeable and possibly suitable for soakaways. However, it was not clear whether the pre-construction soakaway tests had been carried out on the clay, bedrock or both (the level at which soakaway tests are carried out should be shown on sections of the design to make sure the design levels are appropriate). The soakaway was constructed in clay with poor infiltration rather than extending to a deeper layer of mudstone, which had been intercepted by the infiltration test pits.

Following extensive legal proceedings, the solution was to disconnect a large part of the catchment from the existing soakaway and connect it to a new deeper soakaway. The cost of this was significant and required extensive excavations with its associated disruption.

Lessons learnt

- Design drawings should provide adequate and correct detail to inform contractors of how SuDS component should be installed to fulfil their function fully.
- Where an infiltration system should extend into a specific stratum the base level should be stated on design drawings and the excavation should be inspected by the designer.
- Experienced designers and contractors should be appointed to ensure a solid knowledge base has informed the design and build.
- Inspection points should be incorporated into a design to ensure longevity of component.

Handy hint



Always indicate the level that the soakaway testing was carried out on the design drawings.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Infiltration** is the ability of the soil to absorb water.



27 PROPRIETARY TREATMENT SYSTEMS

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Chapter

27

Proprietary treatment systems

This chapter provides information on the issues that may arise when constructing proprietary or manufactured treatment systems and how to avoid them.

- *A construction checklist for proprietary treatment systems is provided in Section 27.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design of proprietary treatment systems can be found in The SuDS Manual (CIRIA C753) Chapter 14.*
- *General information on construction checklists can be found in The SuDS Manual (CIRIA C753) Appendix B6.*

27.1 INTRODUCTION

There are numerous types of proprietary or manufactured treatment systems, some of which are similar to other types of SuDS (proprietary bioretention systems or proprietary tree pits). The proprietary systems referred to specifically in this chapter are those that remove specified pollutants from surface water runoff. The main processes by which pollution is removed are filtration or physical removal (settlement) of fines. Filtration systems can be more prone to blockage by muddy water, so care is required when using these systems to manage runoff during the construction phase of development, unless the system is specifically designed to cope with sediments (and has the manufacturer's guarantee for this). Regardless, they should be cleaned and filters replaced before handing over a site to a client or adopting organisation.

Most proprietary systems are installed below ground and will have specific construction recommendations and guidance provided by the suppliers, which should be read carefully before starting work. In many instances the systems are delivered prefabricated inside a chamber, which makes installation easier and less prone to problems.



Watch point

Read and follow the instructions provided by the supplier.

27.2 CHALLENGES IN CONSTRUCTING PROPRIETARY SYSTEMS

Challenges generally relate to following specific advice from the supplier of a particular system.

1

Getting it right

Make sure construction runoff is not allowed to drain into systems unless the supplier indicates it is acceptable.

What can go wrong

Muddy water from construction runoff can block filters.



Soil mounding in progress close to uncovered proprietary component

2

Getting it right

Proprietary components should be stored on site as specified by the supplier. Some systems are delivered in a protective wrapping to keep debris out of them – do not remove this until it is time to install the unit.

What can go wrong

Exposure to UV light may affect strength of the housing or chamber.

Keep clean at all times, especially filters otherwise they can become clogged or contaminated (eg by fuel).



Proprietary component stored with soil protection cover

3

Getting it right

Proprietary products should be handled during installation as specified by supplier. Do not roll, drop or damage components.

What can go wrong

Improper handling can cause damage to the components and the chamber. Failure to comply with the handling and installation instructions may void warranties and cause poor performance.



Proprietary system with 'no step' notices

4

Getting it right

Ensure installation to correct levels, especially where system is to be installed into a manhole on site – pipe locations and levels should fit unit.

What can go wrong

The system may not operate correctly leading to pollution of rivers and streams or flooding of site.



Extra large flow control set at correct levels in a manhole

5

Getting it right

Ensure outfalls are constructed to correct levels.

What can go wrong

The system may not convey enough or too much water causing insufficient removal of pollution.



Proprietary treatment system installed at the correct levels

6

Getting it right

Filters and casing should be installed in the correct direction.

What can go wrong

If installed the wrong way round, the filter can prevent water flow or reduce treatment effectiveness.



Proprietary treatment chamber installed with inlet stencil

7

Getting it right

All supplied seals and other components should be installed to manufacturer's recommendations and kept clean before and post installation. Elastomeric seals need to be stretched into place evenly.

What can go wrong

Leaks can develop if seals are not correctly installed. If leaks occur this can result in untreated water bypassing the system.



Elastomeric seal being stretched into position

8

Getting it right

Ensure that inspection and cleaning jet points are installed at adequate levels as specified.

What can go wrong

The system may not be easily and properly cleaned.



Lifting hatches incorporated into seating area to allow easy access for inspection and maintenance

9

Getting it right

Backfill should be correctly installed as specified and as per manufacturers' recommendations.

What can go wrong

Incorrect backfill to chambers can cause collapse or flotation.



Extra large flow control set at correct levels in a manhole

27.3 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 27.1 Proprietary treatment systems checklist

	✓
Read and follow suppliers' instructions before receiving delivery to site (ask the site manager for these if they not been provided or download from the manufacturer's website)	
Products and materials are stored on site correctly as described in suppliers' instructions	
Handle products and materials as described in suppliers' instructions	
The base of the excavation is clean and level and at correct depth	
Inlets and outlets are installed the correct way round	
Casing/chamber are installed correctly	
All seals are installed correctly	
Filters etc are installed right way round	
Water flow through the component is tested before covering it up	
Backfill is as specified on design drawings	

CASE STUDY 27.1 Leaking joints and seals

A proprietary treatment system comprising a sectional manhole was installed without sufficient attention being given to the joints and seals when the manhole was put together on site. During a routine inspection, the system was found to be leaking water into the surrounding ground. The system had to be re-excavated and re-assembled so that the joints were correctly sealed. This caused considerable cost and disruption.

Lessons learnt

- Ensure correct installation of components at the time of construction and before covering up the works.



Figure 27.1 Elastomeric seal being correctly stretched into position

CASE STUDY 27.2

Poor installation – not following design drawings/specification



Figure 27.2 Over-filled compacted bioretention planter



Figure 27.3 Correctly installed system with sub-surface ponding area

Proprietary bioretention planters often include a recessed zone to allow for surface water ponding, so the soil filter media is set to a lower level than the surrounding pavement, road surface or nearby landscape. The systems are also filled with specialist filter soils that are not compacted. A system was installed and a well-meaning contractor decided to fill the system up to the same level as the pavement using as-dug material from elsewhere on the site. At the same time, the contractor compacted the soils, including the filter media. Due to the different soils and over-compaction, the system was no longer able to drain freely as designed, nor was the ponding depth on top of the media provided. This lead to surface water ponding on the road rather than within the bioretention planter. The bioretention planter had to be completely emptied of all soil, and then re-filled with soil to the correct specification and to the correct level.

Lessons learnt

- Due care to be taken when handling soils on site to avoid compaction.
- Construction to be carried out as per the design and specification to ensure that SuDS components fulfil their intended function.

CASE STUDY 27.3

Poor installation – not following design drawings/specification



Figure 27.4 Incorrectly positioned bypass inlet

A proprietary treatment system for a car park was designed to treat the one year storm event. The design included a separate bypass gully inlet to allow less frequent, higher volume storms to be drained from the car park surface to an attenuation storage tank. The contractor installed the bypass inlet on the wrong side of the proprietary treatment device. Instead of the flow from the car park being directed first to the proprietary treatment system with higher flows being directed to the bypass inlet, the bypass inlet was receiving all of the flow from the majority of the car park and only a small section of the car park was being treated.

The incorrectly positioned bypass inlet had to be blocked off and a replacement bypass inlet installed in the correct position.

Lessons learnt

- Contractors should ensure they understand both the design intent and construction detailing required before the start of construction.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Elastomeric seals** are rubber rings, highly stretchable and create tight seals.
- **Bioretention systems** are planted components that collect runoff from roofs or hard surfaces, allowing it to pond on the surface and slowly infiltrate into the ground or drainage layer beneath.



28 FILTER STRIPS

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Chapter

28

Filter strips

This chapter provides information on the issues that may arise when constructing filter strips and how to avoid them.

- *A construction checklist for filter strips is provided in Section 28.4.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design and construction of filter strips can be found in The SuDS Manual (CIRIA C753) Chapter 15.*

28.1 INTRODUCTION

Filter strips are grass areas designed to have water running across their surface as a 'sheet flow' before discharging into the next SuDS component in the system (which will be linear in form). They are only suitable for planting with grass, mixed ornamental grasses or a wildflower/grass seed mix where a dense cover at ground level can be produced.

The purpose of a filter strip is to remove sediments from the runoff, and to filter out heavy metals and other pollutants. Where soils are naturally permeable, they may also provide a degree of infiltration. To enable water treatment processes to occur the water flow across the surface should be as slow and as even as possible.



Figure 28.1 Wide grass filter strip on shallow gradient, falling to a filter drain

28.2 CHALLENGES WHEN CONSTRUCTING FILTER STRIPS

Due to the shallow, sloping nature of grass filter strips, most issues relate to ensuring that the water flows slowly and evenly from the drop off the edge of the paving, across its entire surface until it reaches the next SuDS component.

1

Getting it right

Ensure designed shallow falls across paving to filter strip are not increased, as they should be sufficiently shallow to allow a relatively slow and even flow across the strip.

What can go wrong

If the paved area is too steep it will create a high velocity of water causing erosion to surface of filter strip.



Shallow gradients to paving and filter strip

2

Getting it right

Ensure extent of hard surface draining onto any one strip is not increased during construction.

What can go wrong

Excess water will reduce efficiency of strip and may cause erosion.

3

Getting it right

Ensure a drop (50 mm to 100 mm) is provided from the paving to the filter strip. This creates sheet flow evenly across surface of filter.

What can go wrong

Flush or raised grass levels between paving and strip will cause siltation at the junction (over time) with water ponding on the hard surface.



Drop from tarmac road surface onto filter strip

4

Getting it right

Ensure ‘edge protection’ measures (eg bollards or rocks) are suitable for volume and size of vehicles, and are provided to prevent vehicles over-running the filter strip.

What can go wrong

Vehicles will rut the surface and damage its ability to work as designed.



Large rocks used as ‘edge protection’ to road

5

Getting it right

Ensure gradient of strip is even and laid in accordance with the specification (usually between one and five per cent).

What can go wrong

Uneven flow can cause localised ponding or erosion, and may not provide sufficient treatment of pollutants.

Too steep a gradient may allow water to run off quickly to achieve sufficient treatment of pollutants.

6

Getting it right

Ensure that sufficient edge support is provided to the asphalt surface so that it does not fail when trafficked. If edgings or kerbs are used make sure there is sufficient concrete haunching on the filter strip side to support the pavement.

What can go wrong

Lack of edge support can lead to the pavement collapsing towards the filter strip.



Lack of sufficient edge support

7

Getting it right

Ensure an adequate depth of topsoil is provided as per design specification.

What can go wrong

A dense grass sward may not be established.

8

Getting it right

Check any change of specification of grass/ wildflower cover with designer to ensure appropriate mix.

What can go wrong

Vegetation may not achieve sufficiently dense cover and will be eroded.

9

Getting it right

Ensure complete dense establishment of grass or vegetation cover before use.

What can go wrong

Soil erosion in non-vegetated areas. Ability of strip to remove silt/pollutants reduced.

28.3 CHALLENGES WHEN MAINTAINING OR USING INFILTRATION FILTER STRIPS

These challenges relate to the use of permeable soils to ensure that the planned infiltration will occur.

1

Getting it right

Protect on-site soils before construction to preserve natural infiltration.

What can go wrong

Compacted soils prevent infiltration.

2

Getting it right

Ensure specialist permeable soils are used where specified.

What can go wrong

The strip will not infiltrate water as designed if the wrong soil is used.



Handy hint

Use turf, rather than grass seed, if the strip needs to be used immediately. (If using an infiltration strip, ensure turf is not grown on a clay soil, which could inhibit infiltration.)

Where turf has to be used instead of wildflower mix, consider using native wildflower plugs as well.

28.4 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 28.1 Filter strips checklist ✓

For infiltration filter strips (where infiltration is required by the design), check that permeability of soils is still effective following construction	
Where specialist soils are used to promote infiltration, delivered soils comply with the specification. This may require re-testing samples from across the soil storage area	
Completed levels accord with original design drawings (see next point)	
Audit trail of changes to ensure revised scheme still fulfils requirements of the original scheme	
Size of area drained has increased (see next point)	
Sizing of filter strip has been increased to accommodate increased drainage area	
Drop from paved surface to filter strip is continuously at a level of between 50 mm to 100 mm	
Adequate 'edge protection' measures are in place to avoid vehicle overruns	
Level of filter strip is consistently between one and five per cent	
Topsoil depth is as specified	
Seed/turf mix complies with the original specification	
Vegetation is sufficiently dense to withstand water flow to allow runoff across the strip without the soil eroding before being brought into use	

Jargon buster

- A **component** is a drainage feature that can take many different forms.



29 FILTER DRAINS

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Chapter 29

Filter drains

This chapter provides information on the issues that may arise when constructing filter drains and how to avoid them.

- *A construction checklist for filter drains is provided in Section 29.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design and construction of filter drains can be found in The SuDS Manual (CIRIA C753) Chapter 16.*
- *General information on construction checklists can be found in The SuDS Manual (CIRIA C753) Appendix B6.*

29.1 INTRODUCTION

Filter drains are linear trench drains, filled with clean aggregate, designed to store and transport water down the system. They ideally work in conjunction with a filter strip, which filters runoff before it enters the filter drain. Filter drains have an outfall and are different to infiltration trenches.

Filter drains are normally lined (either a geotextile or geomembrane, or the entire drain may be inside a concrete trough), and they almost always have a perforated pipe within the aggregate to assist with drainage. When used in association with a filter strip, silt is removed from the water by the strip before it enters the drain. When not used with a filter strip, a sacrificial layer of stone is included above the geotextile surround to the drain. The stone used to infill the drain should be clean, and is usually sized to allow the maximum storage of water within the gaps in the aggregate, although this is also dependant on the anticipated traffic loading. The drain will require some form of flow control at the end of the system to manage its discharge rate so that the internal storage can be used effectively.

Geocellular systems may be specified as part of a filter drain system to provide a greater water storage capacity (see **Part F Chapter 34**), but should be subject to structural design calculations. The geocellular system will replace some of the aggregate in the trench.



Figure 29.1 Drain sized to take all water from adjacent road through positive falls

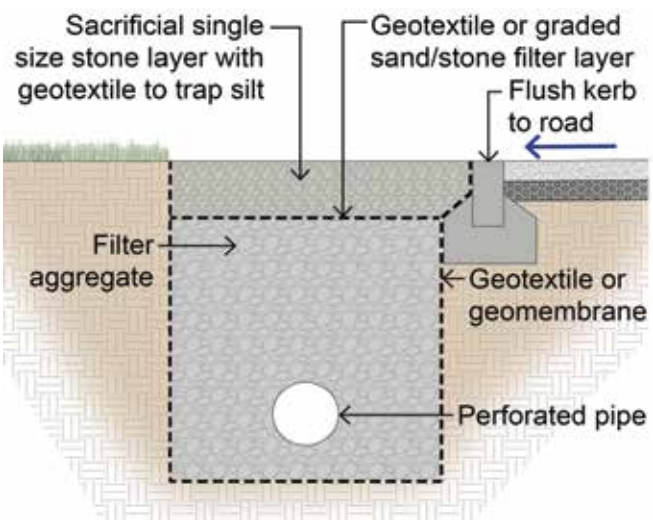


Figure 29.2 Indicative section through roadside filter drain

29.2 CHALLENGES THAT APPLY TO THE CONSTRUCTION OF FILTER DRAINS

The main challenges are that the filter drain is constructed to ensure that the geotextiles and aggregates are installed and maintained in a clean condition at all times, and to ensure it functions as designed. The timing of the installation/site planning is important to prevent muddy water flowing into the drain.

1

Getting it right

Soils in the location of the drain have sufficient permeability.

What can go wrong

System will not drain into surrounding soils.



Flooded filter drain

2

Getting it right

Site operations are planned to avoid silt-laden runoff entering the drain either during its construction or afterwards.

What can go wrong

System will become silted and blocked.

3

Getting it right

The area shown on the design drawings falls towards the drain and has an adequate fall.

What can go wrong

Area will not drain properly.



Area falls correctly to the filter drain

4

Getting it right

The base of the drain falls continuously.

What can go wrong

System may not drain/could backflow, and may not store enough water.



Continuous fall to filter drain

5

Getting it right

The aggregates are the correct size and that the material is clean and does not include fines.

What can go wrong

Insufficient storage and fines will reduce its efficiency due to their small particle size.



Clean aggregate polluted by site soil and fines, will reduce efficiency of filter

6

Getting it right

The trench width and depth is correct.

What can go wrong

Will not store enough water.



Correct width to filter drain

7

Getting it right

The geotextile is as specified and has the correct porosity.

What can go wrong

System unlikely to work as anticipated and may fail. Fines could enter drain and will clog it.



Filter drain under construction with no geotextile wrap used

8

Getting it right

The geotextile is adequately lapped and has no tears or damage to it, and is well secured.

What can go wrong

Fines could enter the drain and clog it.



Insufficient cover to wrapping has caused tears, exposing fill and causing potential clogging

9

Getting it right

An inspection tube (where specified) is installed correctly.

What can go wrong

Functioning of system cannot be checked easily without an inspection tube.

10

Getting it right

A sacrificial layer of geotextile and stone is provided where no upstream filter strip has been used.

What can go wrong

When surface becomes silted, maintenance becomes more difficult and expensive to correct.

11

Getting it right

The outlet is constructed at the correct level, is to the size specified and installed to manufacturer's requirements.

What can go wrong

Discharge will not be regulated to designed flow or too much water will be held back, and may overflow on the surface.

Watch point



Do not allow site drainage to enter the filter drain during construction or it will become silted-up.

29.3 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 29.1 Filter drains checklist

	✓
The area shown on drawings falls adequately towards the drain	
Levels in bottom of trench to ensure a continuous fall	
Adequate stone below invert of drain pipe – sized to pipe diameter	
Trench width and depth is correct	
Geotextile is as specified and has the correct porosity	
Geotextile is lapped and has no tears or damage	
Aggregates are the correct size and the material is clean and does not include fines	
Aggregate size used is in accordance with the specification	
Sacrificial layer of geotextile/stone provided if no filter strip used	
Outlet is the size as specified and is installed at the correct level	

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- A **sacrificial layer or material** is provided as a temporary measure during construction and is removed before the works are completed. In filter drains a sacrificial layer is used that remains in place after construction and is replaced each time maintenance is carried out to clean the surface gravel.



30 SWALES

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30

Swales

This chapter provides information on the problems that may arise when constructing swales and how to avoid them.

- *A construction checklist for swales is provided in Section 30.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design and construction of swales can be found in The SuDS Manual (CIRIA C753) Chapter 17.*

30.1 INTRODUCTION

Swales are similar to shallow ditches, but should be flat-bottomed across their width, and may be used to convey water from one SuDS component or part of a site to another. They may also provide water storage capacity if there is a flow control at the outfall. Where located within suitably permeable soil, they can provide a linear area for infiltration. Swales can be simple grass components or can incorporate planting, and may be under-drained. In some soils, on contaminated land, or where the runoff is more highly polluted swales may need to be lined to prevent infiltration (ideally avoided).

Swales may be fed from an inlet, but can also run parallel to a road or path with water flowing laterally into it. This is called 'over-the-edge' drainage.

30.2 CHALLENGES WHEN CONSTRUCTING SWALES

Typical challenges that can arise when constructing swales relate to the gradient of the banks being too steep, maintaining consistent falls along their length and ensuring that the vegetation is sufficiently established before being used as part of the drainage system. Any changes to the specified plants should be checked to ensure they are suitable for the type of swale proposed.

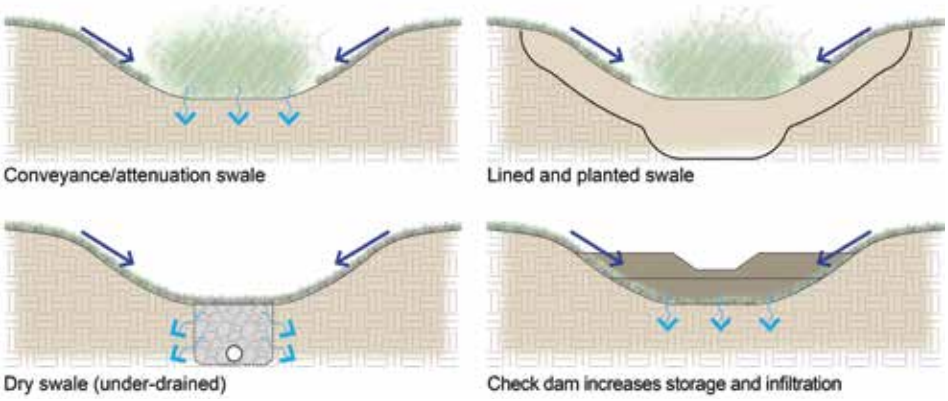


Figure 30.1 Different swales present different construction requirements

1

Getting it right

The correct levels and an even gradient are achieved along the entire length of swale.

What can go wrong

Water may pond along the length of the swale and not drain (unless planned as a marshy swale to hold water).



Poorly constructed, with pebble channel at lower level than swale (note good use of turf to provide well vegetated swale)



Correctly installed levels

2

Getting it right

The correct depth to the swale and levels to inlets and outfalls are constructed.

What can go wrong

May not convey or store enough water.



Levels and base of swale and outfall correct

3

Getting it right

Both the correct depth and quality of topsoil are used in accordance with the specification.

What can go wrong

Planting or seeding may not establish well.



Poor quality soil leads to poorly-established planting

4

Getting it right

The side slopes are not too steep and are in accordance with the design.

What can go wrong

Side slopes that are too steep can cause problems with maintenance, eg mowing

Steeper side slopes may reduce storage capacity and there may be safety implications.



Steep banks and fencing prevents easy maintenance of the channel

5

Getting it right

Soil compaction is avoided to maintain infiltration rates (where desired).

What can go wrong

Compaction reduces how fast water soaks into the ground, which will reduce the system's performance. This may lead to ponding on the surface or flooding further down the system.



Works carried out in drier conditions to avoid over-compaction of soils

6

Getting it right

Where a geomembrane is used, ensure it has adequate cover to avoid exposure to UV light and slippage of the soil on top of it.

What can go wrong

The membrane may be damaged by UV light and could leak.

7

Getting it right

Weir and outlet details are constructed with care to integrate properly with banks.

What can go wrong

Poor interpretation of construction detailing of weirs and inlets may result in visually unacceptable finishes, and could affect capacity or cause erosion. Also likely to be damaged.



Robust solution (but better integrated with gabion around entire pipe)



Simple solution (but surround unnecessarily extensive and end of pipe vulnerable to damage)

8

Getting it right

Grass and vegetation should be well established before use.

What can go wrong

Erosion of soil, with sediments being washed down the system and potentially causing blockages elsewhere.



Swale with erosion

9

Getting it right

Phasing of the planting works is planned relative to general weather conditions/seasonality.

What can go wrong

Limited availability of plants, particularly if specified bare root (which need extensive watering after installation). Frost or excessive rainfall will prevent planting.



Planting is well scheduled within construction phasing to suit seasonality

10

Getting it right

Correct plant species and density of plants and/or seeding are supplied and used, and are planted in the correct location within the swale.

What can go wrong

If plants do not establish, visual quality will be poor and biodiversity potential is reduced. Bare soil will cause washout and siltation. Incorrect plant species may also die.



Plants planted in wrong location and lack of maintenance

Handy hint



Consider turfing the base and up to 300 mm on the side of the swale if it needs to be brought into use quickly.

'Over-the-edge' drainage

The main issue when installing over-the-edge drainage type is ensuring levels at the edge are set so that water can flow off the hard surfaces freely onto the grass while anticipating a degree of siltation over time. The strength/quality of the road edge construction is equally important.

1

Getting it right

There are sufficient gaps in the kerb, or the grass is slightly lower than the nearby hard surface, and the grass falls away from this surface, to allow the water to run in freely.

What can go wrong

Water ponds on hard surface and will not flow into the swale.



Large opening in kerb allows for extensive flow water into planted swale

2

Getting it right

Kerbs or edgings are sufficiently haunched to provide support to the pavement, but will still allow grass or planting to grow up to the edge.

What can go wrong

Potential failure of the kerb and road surface caused by downwards and sideways pressure from weight of vehicles where haunching is insufficiently robust.



Haunching around kerb does not allow enough topsoil for good vegetation establishment



Construction of kerb line allows vegetation growth to edge of swale

Dry swales (under-drained)

Dry swales generally occur where under-drained swales have check-dams.

1

Getting it right

Correct material is used in the base of swale where specified as free-draining granular material.

What can go wrong

Standing water occurs where not wanted or planned, which may also reduce storage or conveyance capacity due to reduced infiltration.



Sandy root zone material in base of swale

2

Getting it right

Geotextile that meets the specification is used to protect under-drained pipe and surround.

What can go wrong

Incorrect porosity of geotextile may impede flows from the swale to the pipe.

30.3 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 30.1 Swales checklist

	✓
Completed levels along length of system and at weirs/outfalls agree with original design drawings, if not (see next point)	
Audit trail of changes to ensure revised scheme still fulfils requirements of the original design criteria and specification	
Gradient of side slopes and width of base to swale are as designed	
Soil permeability for infiltration swales is as specified	
Depth and cover of membrane where used are as designed	
Seed/turf mix or plants supplied comply with the original specification	
Vegetation is sufficiently dense to withstand water flow before use	
Level of grass/road edge where ‘over-the-edge drainage is used is as designed	
Drainage material and pipe in under-drained swales are as specified	
Correct geotextile provided to underdrain and pipe are as specified	

CASE STUDY 30.1

Incorrect planting



Figure 30.2 Poor establishment of planting and poor aesthetic due to planting in wrong locations

Full planting plans and schedules had been produced for the construction of a swale, which showed the appropriate topsoil depth and plant locations within it. However, when inspected after planting, many plants were not in the correct locations as shown on the design drawings. This was due to the contractor using unskilled staff with little knowledge of plants and an understanding of the importance of planting them in the correct locations for the swale to function well. There was also no supervision of the planting. Where planting was carried out by volunteers under the supervision of experienced staff, it was in the correct position.

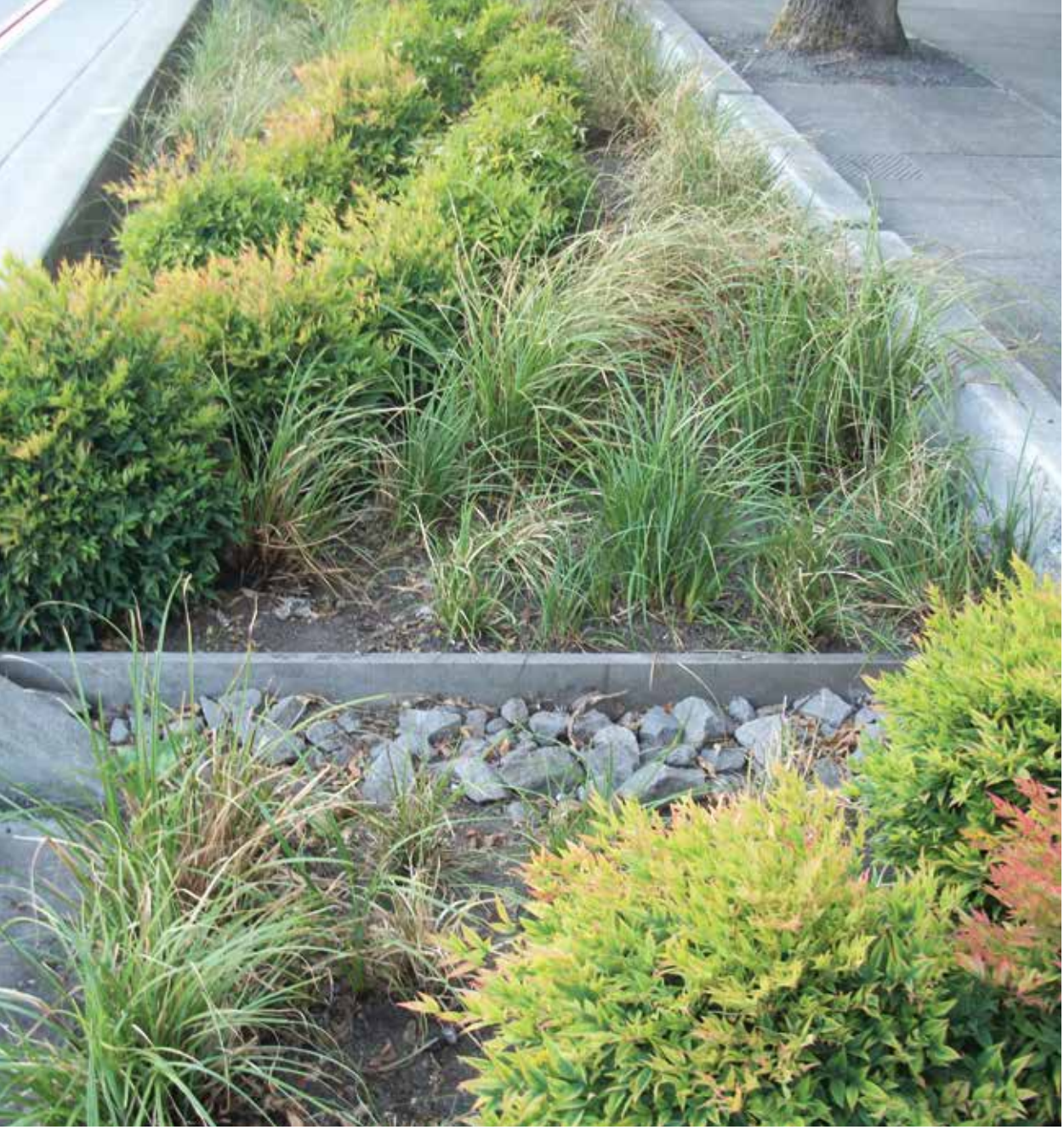
Much of the planting had to be lifted and replanted in the correct positions, and the resulting scheme then established well.

Lessons learnt

- To ensure that the contractor undertaking the planting works is a reputable landscape contractor, who understands the design requirements and the need for careful plant placement, as shown on the design drawings.
- The need to inspect the setting out of plants before planting, and for regular meetings and site visits before, during and after construction to ensure good communication and monitoring of the works.
- Supervision of unskilled staff is required.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Infiltration** is the ability of the soil to absorb water.



31 BIORETENTION SYSTEMS

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Chapter 31

Bioretention systems

This chapter considers the challenges that may arise when constructing bioretention systems (including rain gardens) and how to avoid them.

- *Information on the soils to be used in bioretention systems is provided in Part E Chapter 21.*
- *A construction checklist for bioretention systems is provided in Section 31.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design and construction of bioretention systems can be found in The SuDS Manual (CIRIA C753) Chapter 18.*
- *General information on construction checklists can be found in The SuDS Manual (CIRIA C753) Appendix B6.*

31.1 INTRODUCTION

Bioretention systems are planted SuDS components that collect runoff from roofs or hard surfaces, allowing it to pond on the surface and slowly infiltrate into the ground, or connect into a drainage system. Bioretention systems also include components that have historically been known as rain gardens and stormwater planters, reflecting their use at both a domestic scale and within streetscapes. Bioretention swales are similar to under-drained swales but have a deep, broad area of engineered soil throughout their base (see **Part F Chapter 30**).

All systems (except the smallest domestic scale rain gardens) use an engineered soil as both a growing medium for the plants, and to allow water to filter easily through to the drainage system or infiltration surface beneath. They can be widely variable in their scale, appearance and design, although their construction complies with the same drainage principles. Where designed appropriately, these systems can provide significant water storage capacity and sufficient rooting areas even for large trees. Planting for bioretention systems should be tolerant of dry soil conditions as they are both free-draining, and likely to be dry much of the time. Filtering water through planted systems also improves water quality.

Figures 31.1 to 31.8 illustrate the range of bioretention systems, and how they work.

Where water does not infiltrate, it is important that it is connected into a sub-surface drainage system to ensure that the rooting area of the vegetation drains effectively (over a 24 to 48 hour period). Plant roots that sit in water over an extended time are likely to die. An overflow may also be required to deal with storm events beyond the design capacity of the system.



Figure 31.1 Small domestic rain garden

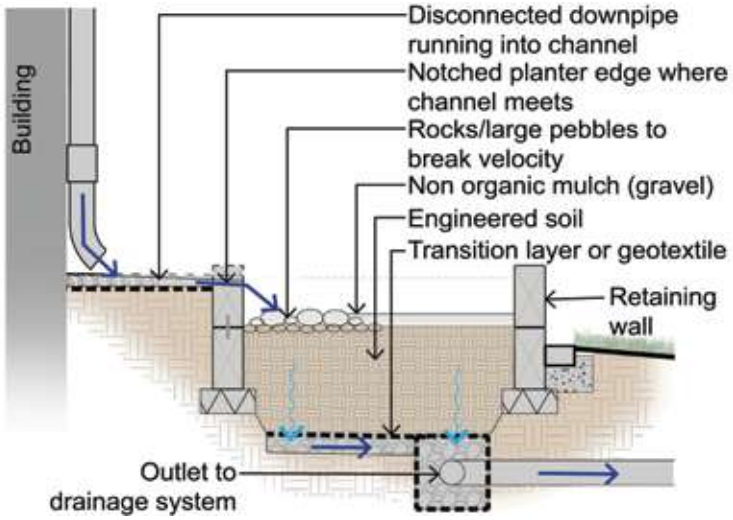


Figure 31.2 Cross section through rain garden



Figure 31.3 Bioretention planter

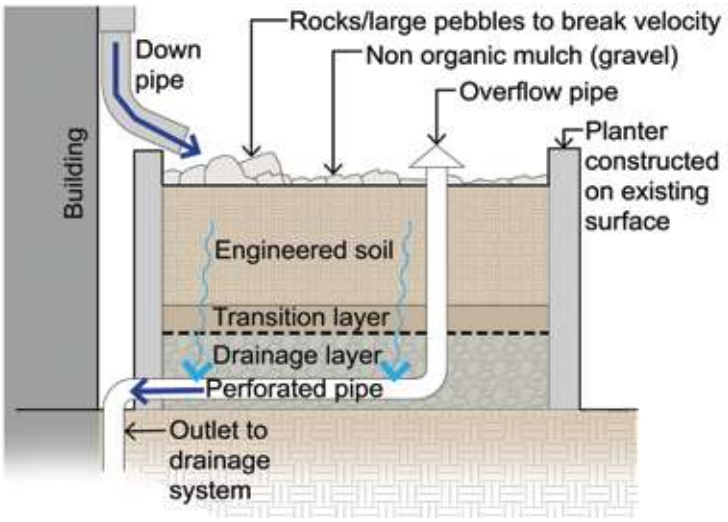


Figure 31.4 Cross section through bioretention planter from disconnected downpipe



Figure 31.5 Bioretention planter in street

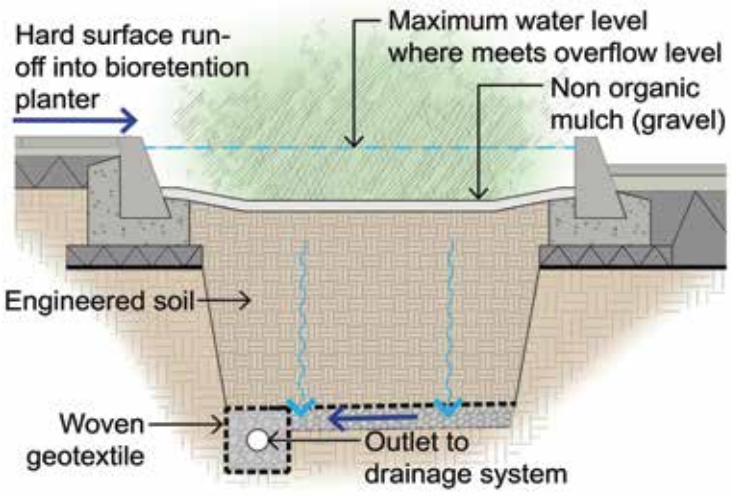


Figure 31.6 Section through bioretention planter



Figure 31.7 Bioretention swale

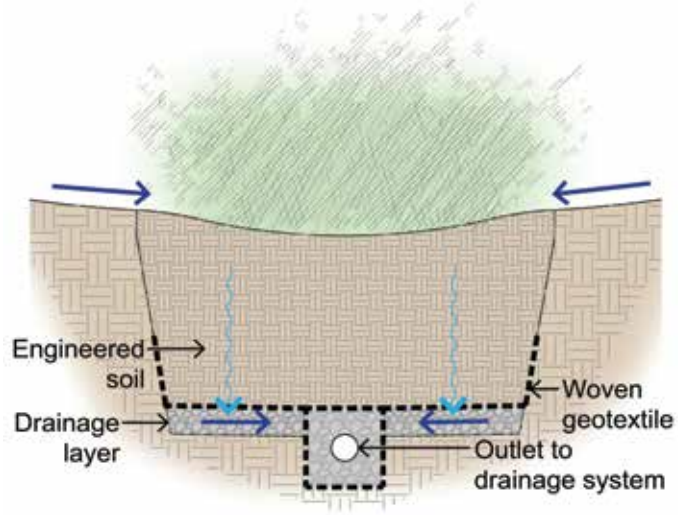


Figure 31.8 Section through bioretention swale

31.2 CHALLENGES WHEN CONSTRUCTING BIORETENTION SYSTEMS

Issues arising from constructing bioretention systems include the materials used, and their compliance to the specification and use within the system.

1

Getting it right

Ensure engineered soil mix, whether proprietary or mixed on site, complies with the particle size and proportions as specified.

What can go wrong

Too open a mix will drain too quickly, while insufficient organic content will not allow plants to establish properly.



Incorrect soil mix, does not drain sufficiently

2

Getting it right

Ensure depth of engineered soil mix is correct.

What can go wrong

System will not provide its designed storage capacity, or the soil volumes may not be sufficient for the specified plants or trees.



Bioretention system filled with specified engineered soil mix

3

Getting it right

Confirm geotextiles are as ordered/received (if used) and comply with specification for porosity.

What can go wrong

If too fine, geotextile may clog reducing water flow through geotextile causing water to be held back within planter. May cause flooding or kill the plants.

4

Getting it right

Transition zone material (if used) should be correct particle size and depth as specified – depth at least 100 mm.

What can go wrong

Insufficient depth or incorrect particle size will cause clogging and prevent effective drainage or it will be washed out and cause the system to stop working.

5

Getting it right

Ensure geotextiles are adequately lapped, and not damaged or torn.

What can go wrong

Silt may wash into drainage layer and clog aggregate reducing its discharge rate/cause it to back up.



Inspecting installation of gravel drain with geotextile wrapping

6

Getting it right

Check dams should be set at correct level and interval to allow designed volume of water to be stored.

What can go wrong

On sloping sites insufficient water will be stored.



Accumulating fall between check dams set at moderate intervals

7

Getting it right

Where an overflow system is provided, it should be set at the correct level (this may not be required for domestic-scale rain gardens).

What can go wrong

Extreme rainfall beyond capacity of system may flood local areas.



Overflow pipe connects to base drainage, with second overflow over the edge for extreme events

8

Getting it right

Only use plants as specified in correct numbers and sizes. Seek confirmation that plant changes are suitable species that meet the design requirements.

What can go wrong

Plants are likely to die if not suited to a system that is mainly dry and only wet when it rains.



Plant species and setting out inspected on site before planting

9

Getting it right

Ensure that mulches are not specified as organic loose materials – ideally gravel.

What can go wrong

Loose mulches can block overflows and will be washed down the system by water on the surface.



Surface mulched with gravel not bark

Hard edged/roadside systems

Most issues occur around the inlets to the system, ensuring water enters the system freely and at the correct rate, and that silt is trapped before the water flows into the engineered soil mix.

1

Getting it right

Ensure inlets are set at correct angle and level so water flows properly into the system.

What can go wrong

If the inlet bends at too sharp an angle or if the road camber is incorrect, water flowing at speed along a kerb edge may bypass the system.



Angle of inlet and apron encourages inflow

2

Getting it right

Velocity of water through inlet should not erode/ scour soils or damage plants. Ensure components designed to break flows are installed at correct location and level.

What can go wrong

Too fast a flow can erode soils and damage or kill plants.



Setts break velocity, but set too high so needed changing

3

Getting it right

Check forebays are used to create a spread of water to allow silt to settle and water to flow evenly into main system.

What can go wrong

Silt flows into and builds up in the system, which clogs up free drainage of engineered soil.



Forebay with planting to trap silt and debris

Constructing/installing bioretention attenuation storage systems or infiltration systems

Issues relate to lack of drainage, whether due to loss of infiltration in the soil or through inadequately installed piped systems.

Infiltration systems

1

Getting it right

Check base of the system before construction, and ensure the base is free draining to design capacity before filling with engineered soil mix. Remediate if necessary.

2

Getting it right

Ensure drainage pipe is provided in the base and connected to the downstream system.

Attenuation storage systems

What can go wrong

Water will not drain or drains slowly, causing flooding, lack of storage and/or killing plants.

What can go wrong

If incorrectly installed, water will not drain or only drain slowly, potentially causing flooding through lack of storage and may kill the plants.

31.3 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 31.1 Bioretention systems checklist ✓

Where infiltration is required by the design ensure that permeability of natural soils is effective and delivers the design infiltration capacity	
Particle size of delivered engineered soils or individual soil elements for site mix comply with specification	
Depth of engineered soil is as designed/specified and undertake on-site permeability test to check soils drainage capacity	
Audit trail of changes to ensure revisions to scheme still fulfil requirements in-line with original scheme	
Graded filter or geotextile used, and compliance to specified materials/depth	
Piped drains are installed in base of system and connected to main drainage system correctly (not infiltration systems)	
Overflow system is in place, and functioning correctly	
Inspection tube installed correctly	
Plant sizes and species are supplied and located to the correct specification and design	
Organic soil mulches have not been used	
Specified components are in the correct place to break inlet velocity	
Where forebays are used, finished levels allow even flow of water into system	

CASE STUDY 31.1

Poor levels in a rain garden



Figure 31.19 Level of soil above the level of inlets from road

The design for a rain garden showed a basin that had its base below the level of the nearby road with 1:3 side slopes. The design was not understood by the contractor who filled parts of the basin with topsoil to a level above that of the inlets from the highways. This prevented water from entering the rain gardens and removed much of the storage volume as water could not reach areas where the basin had been constructed correctly. A scheduled inspection at the end of excavation was not completed and the biorientation area was planted. The problem with the levels was discovered after the planting had been completed. The plants had to be removed and then replanted once re-contouring to the design profile was completed.

Lessons learnt

- The importance of site visits and hold points during construction, as well as ensuring shared understanding of the scheme between designer and contractor.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- A **forebay** is a small basin up-hill of a drainage component, designed to trap silt.
- **Infiltration** is the ability of the soil to absorb water.
- A **swale** is a SuDS component that is similar to a wide shallow ditch, but flat bottomed.
- **Engineered soils** are designed and manufactured to provide specific drainage and horticultural properties.



32 TREES

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32.2 How are the different types of SuDS tree pits constructed? 197
32.3 What are the challenges in constructing SuDS tree pits? 198
32.4 Good practice checklist 202

Chapter

32

Trees

This chapter provides information on the problems that may arise when constructing tree pits or trenches incorporating SuDS, and how to avoid them.

- *A construction checklist for trees and SuDS is provided in Section 32.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the use of trees with SuDS can be found in The SuDS Manual (CIRIA C753) Chapter 19.*
- *General information on construction checklists can be found in The SuDS Manual (CIRIA C753) Appendix B6.*

32.1 INTRODUCTION

What is the value of using trees with SuDS?

Trees are often an important part of a SuDS scheme. They draw large amounts of water up through the soil, and their leaves catch and slow down rain before it hits the ground. As the tree's roots grow through the soil its ability to take up water increases, and the roots improve soil permeability. Roots can also absorb small amounts of pollutants from the soil.

How can trees be used in SuDS?

Trees can be used in most SuDS components, and will improve the performance of infiltration systems such as swales, bioretention areas and detention basins. They can also be used in attenuation components such as wetlands or alongside ponds. Trees can be used on their own within paved areas, where the rooting area of the tree forms part of the SuDS.

Trees generally require a wider rooting area than is commonly assumed and the majority of their roots are near the surface. While this is less of a factor when planted in open space, it is a major constraint within an urban area such as a street. This chapter will mainly focus on trees set within paved areas, where getting the construction right is important to both its SuDS performance, and for the tree to grow well.

32.2 HOW ARE THE DIFFERENT TYPES OF SUDS TREE PITS CONSTRUCTED?

The different types of SuDS tree pits

How the tree pit is constructed depends on how the growing medium/soil is provided. Each method of construction has to provide both structural support for the paving above, as well as suitable soil conditions for the tree. The construction uses either structural soils, or soils used along with modular or raft systems. Structural soils are mainly sand or rock, mixed with soil and fertiliser. The sand/rock part allows the soils to be compacted sufficiently for paving to be constructed on top, while still allowing tree roots to grow through it.

1 Structural soils can be provided as:
   a sand-based soils, also known as tree soils (**Figure 32.1**)
   b medium-sized aggregate soils
   c larger stone aggregate material known as stone skeleton soils (also known as the Stockholm system) (**Figure 32.2**).

2 Modular structures are filled with soils (**Figure 32.3**) and the structural support provided as:
   a plastic, concrete, or combined plastic/steel or plastic/concrete structures.

3 Raft systems are laid above the soils (**Figure 32.4**) and the structural support provided as:
   a cellular confinement systems/geocells
   b geocellular sub-base replacement systems.

Other construction items that may be required

Depending on whether the subsoil is suitable for infiltration or not, and the location of the SuDS to buildings or roads, additional construction features may be required, for example:

- an overflow to drain the base of the tree pit where infiltration is insufficient
- lining of the tree pit with a membrane where there are groundwater or contamination issues
- tree root barriers to prevent sideways growth near to services, roads or buildings (also depends on tree species planted).

These may be required regardless of the type of tree pit construction.

32.3 WHAT ARE THE CHALLENGES IN CONSTRUCTING SUDS TREE PITS?

Many of the issues relate to ensuring that the growing conditions within the tree pit are correct and will provide for the long-term health of the tree.

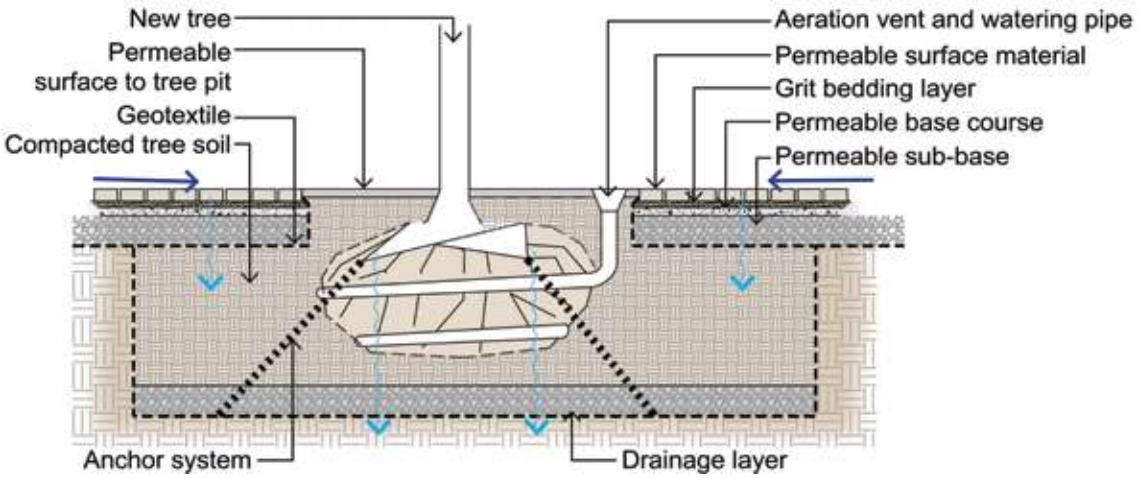


Figure 32.1 Tree pit with sand-based structural soils

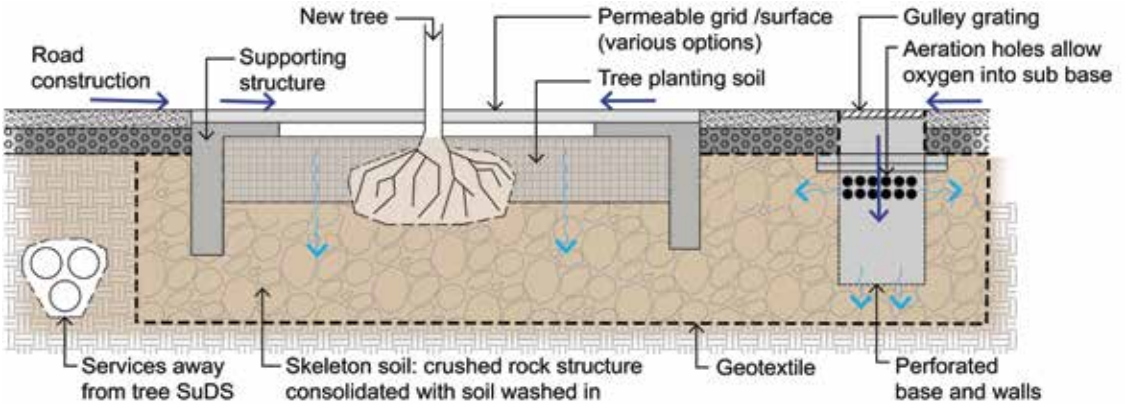


Figure 32.2 Tree pit with structural skeleton soils

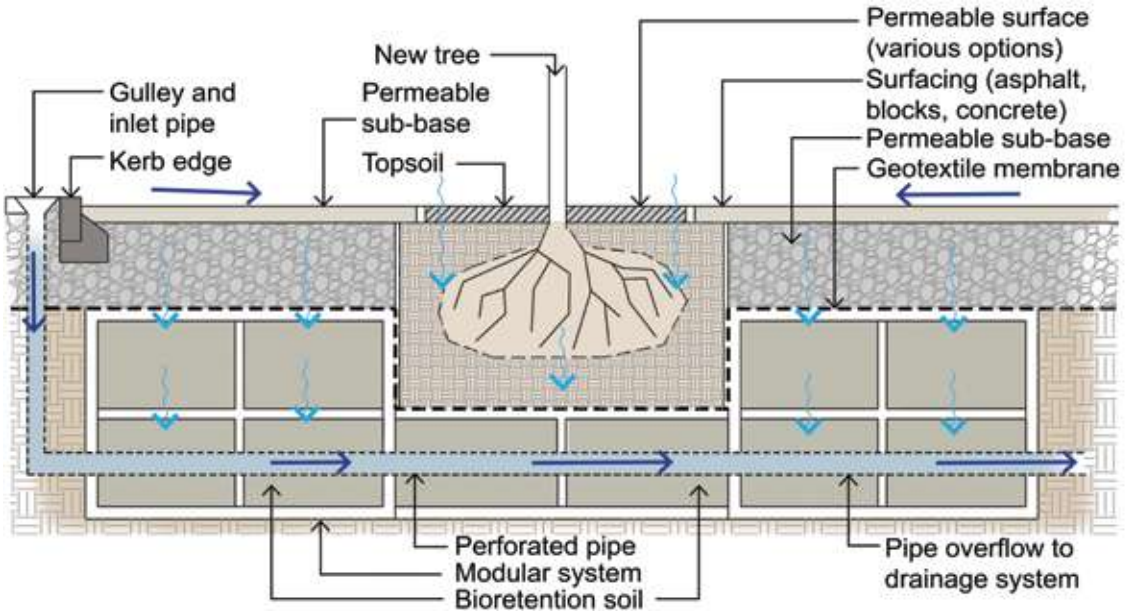


Figure 32.3 Tree pit with modular structures filled with soil

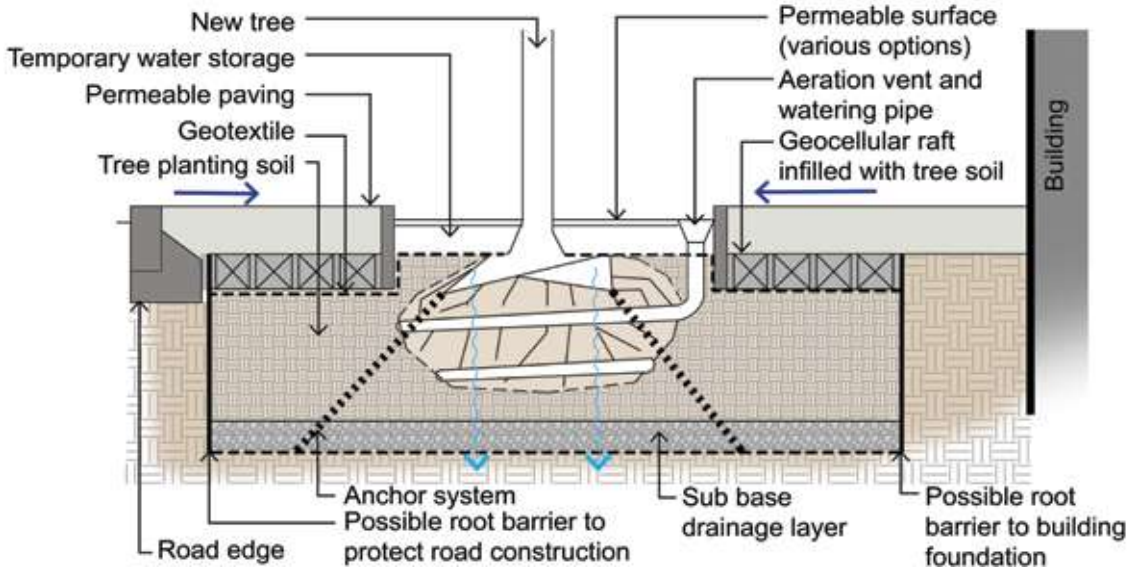


Figure 32.4 Tree pit with raft system using geocellular sub-base replacement

1

Getting it right

SuDS tree pits are only designed to take water from the paving around them. Ensure that the area falling to each tree pit is as shown on the design drawings.

What can go wrong

Connecting water from several gullies or roof downpipes can overload and waterlog the below ground system. This may kill the tree and cause flooding.



Inflow to tree pit restricted to defined inlets only

2

Getting it right

The tree pit should be wide rather than deep to provide the required soil volume to cope with growing roots – this should not be changed from the design drawings.

What can go wrong

Limited space encourages deep pits, but few roots grow at depths greater than a metre. Tree may not grow to its expected size if deep tree pits used.



Broad tree rooting area contained in crates

3

Getting it right

The correct volume of soil should be provided to the correct mix as specified.

What can go wrong

Insufficient soil will restrict ability of tree to grow, which will reduce its ability to absorb water. Soil with the incorrect permeability or with the incorrect mix of basic materials may not allow water to flow through quickly enough and could cause waterlogging and surface flooding around the tree.



Waterlogging caused by compacted soil with poor permeability

4

Getting it right

Where overlying surfacing is required, use a pervious surface to the tree pit and/or provide an aeration pipe.

What can go wrong

Tarmac or other impermeable materials used right up to trunk can cause roots to lift the paving and/or can kill the tree by preventing air and water reaching the roots.



Tarmac laid up to the tree trunk, with lifting due to root action

5

Getting it right

Main water storage system should be located below the main rooting area.

What can go wrong

Excess volumes of water held regularly within the rootball so that it is saturated can kill the tree by creating anaerobic conditions.

6

Getting it right

Overflow pipe installed where infiltration is low.

What can go wrong

Rooting area fills with water, and only drains very slowly. May kill the tree.

7

Getting it right

The tree species, size/condition are as specified.

What can go wrong

The wrong species, or planted at the wrong size, may not grow well within the designed tree pit. If the tree is planted too small it is also likely to be subject to vandalism within urban areas.

8

Getting it right

Excavations should be hand dug where SuDS is retrofitted next to existing trees.

What can go wrong

Advice required from arborist to prevent damage to trees. Sufficient time for hand-digging needs to be programmed in.



Over-excavation and hand digging not used directly around existing trees during SuDS retro-fitting

Avoiding damage to nearby services/structures

Trees may be grown relatively close to buildings, road bases and services, providing the designer has addressed the issue of roots causing damage in the design of the tree pit. Root barriers are a useful product to prevent damage. Regardless of whether the tree pits are being retrofitted or part of a new scheme, it is important to ensure that all services and utilities are co-ordinated and located outside the SuDS, and that potential damage to either the services or trees is avoided. New-build schemes should co-ordinate services appropriately, but retrofit schemes may need to be adjusted on site (with the agreement of the designer) if service locations are not in the position shown on the services survey.

1

Getting it right

Use of root barriers to prevent tree root damage to nearby buildings/roads.

What can go wrong

Buildings or road base is damaged over time from tree roots growing into them.

2

Getting it right

Utilities are grouped together outside of the area being excavated for SuDS.

What can go wrong

Un-coordinated installation of services may mean some tree pits cannot be constructed, or services will have to be moved. Tree roots may be damaged if service excavation required.

32.4 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 32.1 Trees checklist

	✓
Runoff areas connected to each tree pit are as designed	
Soil volumes provided are as specified	
Soil mix, depth and width of installation are as specified	
Services do not conflict with tree pits, and are located outside drainage zone	
Surface of tree pit allows aeration of soil below using an aeration pipe (or other agreed means)	
Overflow pipe is provided where soils do not infiltrate	
Tree root barriers are installed where required	
Proposed and actual location of utilities are given – seek advice if within proposed SuDS area	

CASE STUDY 32.1 Inadequate protection of trees



Figure 32.5 Excavation around existing street trees causing root damage

The design for a roadside swale also included the installation of Stockholm/skeleton tree soils around existing tree roots. The installation of the tree soils required excavation around the existing street trees. The contractors started excavations to install skeleton soils. The weather was hot at the time of works, and no consideration had been given to the protection of the trees during the construction works. Due to the weather conditions, during excavation tree roots were damaged and left exposed to the hot weather. The tree officer stopped the works.

This problem was resolved by revising the design on site and avoiding further excavation (which satisfied the tree officer). The thickness of the layers of tree soil required was reduced so that the excavations did not damage tree roots. The design was changed from a swale to large drained tree pits, with the footpath graded towards the tree pits. This would ensure the long-term health of the trees.

Lessons learnt

- Communication is important to ensure that designs are appropriate to their location. There is a need for the designer and contractor to discuss the works before construction begins.

CASE STUDY 32.2

Underground services and trees



Figure 32.6 Unexpected services encountered during street excavation works

The design for SuDS tree pits in a street required the use of modular soil-filled structures to provide the structural support despite carrying out trial holes. During excavation of the tree pits, unexpected utilities were discovered in the proposed locations despite carrying out trial holes and full ground penetrating radar surveying before the SuDS was designed. This was eventually overcome by consulting regularly with the designer as works progressed to change the design to fit around the services found, while still maximising the space for SuDS. There were several occasions when the work was stopped while the designs were re-configured.

The solution involved using aggregate to provide the structural support instead of the originally proposed modular structures where the pre-fabricated rectangular structures would not fit. This meant that the designers could maximise the volume of soil and attenuation by using irregularly-shaped volumes within areas where there were tight constraints, while also ensuring that each utility was protected.

Lessons learnt

- Having an experienced designer over-seeing the construction phase ensures a higher level of informed flexibility to adapt the design.
- It is an advantage if the design for SuDS in streets is easily adaptable to deal with unexpected services.

CASE STUDY 32.3

Compaction of soils around trees



Figure 32.7 Tree with heavily flooded tree pit

The development of a brownfield ex-industrial site included multiple trees. The trees died soon after planting, and tree pits were visibly flooded. Upon investigation, it was found that surrounding soil was overly compacted, which reduced its permeability. Water was soaking into the less compacted soil of the tree pits, but was not draining freely from the pits. The standing water became stagnant, creating anaerobic toxic soil conditions that killed the trees.

The solution was to de-compact surrounding sub-soil and replace the tree and anaerobic soil within the tree pit.

Lessons learnt

- The condition of surrounding soils and sub-soils is as important as consideration of the soils specified within the landscape works.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Infiltration** is the ability of the soil to absorb water.
- A **swale** is a SuDS component that is similar to a wide shallow ditch, but with a flat bottom.



33 PERVIOUS PAVEMENTS

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33.2 Challenges when constructing pervious pavements 208
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Chapter

33

Pervious pavements

This chapter provides information on the challenges that may arise when constructing pervious pavements and how to avoid them.

- *A construction checklist for pervious pavements is provided in Section 33.3.*
- *General construction checklists are provided at Appendix A1.*
- *Detailed guidance on the design and construction of pervious pavements can be found in The SuDS Manual (CIRIA C753) Chapter 20.*
- *General information on construction checklists can be found in The SuDS Manual (CIRIA C753) Appendix B6.*

33.1 INTRODUCTION

There are several types of pervious pavement. The main types of surfacing include block permeable paving, porous asphalt, porous concrete, resin-bound gravel, reinforced grass and gravel.



a Block permeable paving



b Porous asphalt



c Porous concrete



d Resin bound aggregate



e Reinforced grass



f Loose laid gravel

Figure 33.1 Different types of pervious paving

Pervious paving is different to normal paving as rather than using gullies and channels to drain water away, the water soaks through gaps in the surface of the paving and into the sub-base below. The different pervious surfaces have a similar type of sub-base construction below the surface that is permeable and is able to store and move water without losing strength (see **Figures 33.2 and 33.3**).

The water can either soak into the ground below or it can be collected in perforated pipes, geocellular units or fin drains and drained to somewhere such as a sewer or other part of the drainage system.

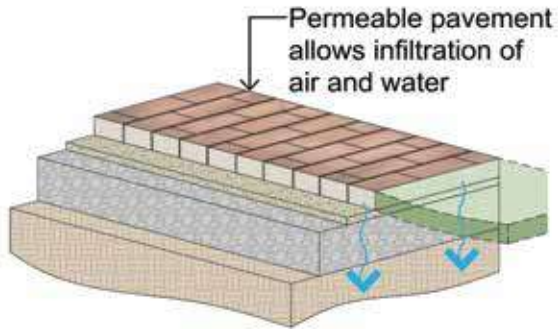


Figure 33.2 Water soaking into the ground

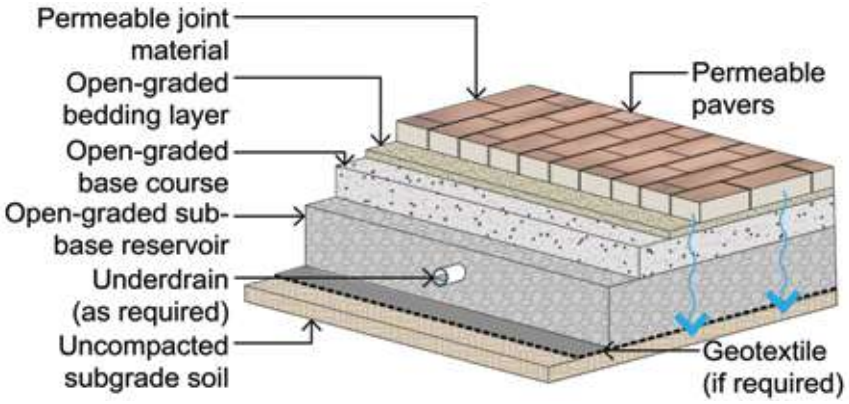


Figure 33.3 Water collected in perforated pipes

33.2 CHALLENGES WHEN CONSTRUCTING PERVIOUS PAVEMENTS

Many of the issues apply to the below-ground construction and so are relevant to all types of pervious surface regardless of their surface finish.

1

Getting it right

The geomembrane (waterproof) and/or geotextile are located in the right place and as specified in the design.

What can go wrong

Using the wrong type of geomembrane or geotextile, or using either in the wrong place, can cause flooding or structural weakness in the pavement.



Geomembrane – prevents flow of water (waterproof sheet – normally rubber or plastic)



Geotextile – permeable (water will flow through it). Allows water to pass through. Geotextile during heavy rain shows no ponding

2

Getting it right

The geomembrane is installed up the side of the sub-base to the correct height – to prevent water overtopping and reaching subgrade. Also to allow joint grit to have full friction against kerbs/edgings. Allow for settlement of membrane sides when weight of sub-base pulls down the membrane.

What can go wrong

If the membrane does not come up the sides far enough it will not provide enough storage capacity.

If the membrane is too high it can reduce friction between the joint infill and the kerbs and edgings, which may allow movement in the blocks.



Geotextile and geomembrane run up side of trench

3

Getting it right

Joints and service penetrations through geomembrane are sealed properly with Top Hats.

What can go wrong

If joints and penetrations are not sealed or the membrane is punctured it will leak and weaken the soil below.



Top Hat seal to membrane around a pipe

4

Getting it right

Only specified materials are used. Type 3 or other sub-base materials do not have much fine material and are highly permeable. Laying course should always be grit not sand.

What can go wrong

Using the wrong materials may result in them not being permeable enough or not providing enough storage. This will cause ponding or flooding.

Equally, the materials may not be strong enough and the pavement may crack or settle too much.



Layer of sub-base below laying surface is permeable and water flows into it easily



Type 3 sub-base

5

Getting it right

Make sure ground is suitable (ie no sharp projections) or protection is provided. Driving on top of membranes should be forbidden – membranes are protected from access by pedestrians or vehicles after they are laid.

What can go wrong

Membrane can be damaged and then leak.

6

Getting it right

The sub-base is not over-compacted.

What can go wrong

Too much compaction causes troughs and ridges in the sub-base and makes it difficult to achieve correct levels. Counter intuitively this results in under compaction of the sub-base as the rutting loosens it.

7

Getting it right

Works should be planned to avoid trafficking on the sub-base – the surface is unstable and could tear up easily leading to loss of levels (especially skid steer loaders and mechanical screeding). Trafficking by construction plant on the finished surface should also be avoided. However, if plant is required to traffic the sub-base it should be covered with a protective layer of asphalt, which is then cored to allow water through it. The correct size and spacing of holes should be cored and they should be filled with the correct grit material, all as specified on the design drawings.

What can go wrong

Damage to sub-base and its rectification can lead to delays in construction and additional cost.

Note that designers need to consider the construction requirements when deciding where to use pervious surfaces.

Mud on any layer of the pervious construction can clog it up and cause water to stand or flooding.

Smaller hole size in dense bitumen macadam than specified or filling with wrong material can lead to surface flooding.



Layer of asphalt used to protect sub-base while it is used for construction traffic – then cored before final finishes
Sub-base reservoir with contamination of material by fines and soil from nearby bank will clog sub-base

8

Getting it right

The subgrade should be protected where the system is designed to allow infiltration (water soaking into the ground). These areas should not be over compacted (and are unlikely to be suitable for storage of materials).

What can go wrong

Compaction of the subgrade reduces the speed at which water soaks into the ground, so will reduce the system's performance. This could cause ponding on the surface or flooding further down the system.



Compaction of subgrade below permeable paving intended to allow water to soak into ground

9

Getting it right

Concrete should not be mixed or stored on the surface of sub-base or finished surfaces, nor should any other materials that may clog the surface.

What can go wrong

It will clog the materials and cause flooding.



Site materials allowed to spread on finished surface will clog surface and it will need to be remediated

10

Getting it right

Topsoil laid in beds next to permeable paving should be set at lower level to the edge.

Kerbs or edgings should be sufficiently haunched, but still allow grass or planting to grow to the edge.

What can go wrong

If topsoil (or mulch) spills onto the pervious surface it can clog it up and cause water to stand or flooding.

Potential failure of the kerb and road surface or alternatively, grass or planting is unable to grow up to edge of paving.



Levels of soil and mulch below pervious paving

Permeable block paving

The points listed here are specific to permeable paving in SuDS – all normal good practice in block laying should be followed unless indicated otherwise here or by the designer.

1

Getting it right

Generally, for trafficked areas, the blocks are laid in a Herringbone pattern. Provide a soldier course around the edge along with a good edge restraint (kerb or edging).

What can go wrong

The blocks can move and spread over time, which leads to structural failure of the pavement.



Well detailed strong edge restraint with herringbone paving

2

Getting it right

Ensure the joints are completely filled with jointing material specified by manufacturer (different blocks have different gap spacing). Blocks may need a return visit to top up after three months of traffic.

What can go wrong

Blocks move and grind jointing material away resulting in rutting and failure.



Absence of grit in joints allows blocks to move

3

Getting it right

Ensure the correct paving units are supplied and installed as specified.

Supplied batches of blocks are batch checked for compliance with the specification and other supplied batches.

What can go wrong

Normal blocks do not allow for sufficient space between them for grit and water.



This pavement was designed to be permeable, but was constructed with normal blocks and sand jointing, so the area flooded. Note that there is one permeable block with end cut outs, circled in red

4

Getting it right

The block laying process recommended by Interlay should be followed. The process for blocks with spacer nibs that are hand-laid is:

- spread the laying course
- screed the laying course
- lay the blocks
- compact the blocks into laying course without jointing material
- add jointing material and compact.

For blocks without spacer nibs the joints may be partially filled before compaction of the blocks into the laying course

What can go wrong

Placing jointing material before compaction of blocks results in loss of line and level on surface.



Compaction before jointing of permeable blocks

Porous asphalt

The points listed here are specific to porous asphalt in SuDS – all normal good practice in asphalt laying should be followed unless indicated otherwise here or by the designer.

1

Getting it right

Prepare sub-base layer for asphalt machine by blinding the top with a stabilising layer of finer material if necessary.

What can go wrong

The stabilising layer reduces movement of the sub-base under the wheels of the asphalt laying machine. Without it the sub-base can rut up, which causes variable thickness of asphalt layer.

2

Getting it right

Do not use tack coats between layers of porous asphalt. To obtain good adhesion between layers minimise time between placing layers, keep lower layer clean of dust and moisture and minimise traffic on lower layer.

What can go wrong

Tack coats will seal the surface and stop water flowing through it leading to flooding.

Poor adhesion between layers weakens the structure.

3

Getting it right

Use a correct paving machine that can spread and finish the mixture without causing segregation.

What can go wrong

Vehicle weight ruts up the sub-base.



Correct paving machine used

4

Getting it right

Plan the works to avoid running asphalt delivery trucks over the prepared sub-base as far as possible.

What can go wrong

Segregation will result in a weaker pavement and uneven drainage of water.

Porous concrete

The points listed here relate only to SuDS construction – normal good practice in relation to concrete laying should be followed unless stated otherwise here or by the designer.

1

Getting it right

Weather conditions should be taken into account when laying.

What can go wrong

Dehydration of the concrete can occur in warm weather leading to weak concrete.

Cement paste washed off in rain leads to weak concrete.

2

Getting it right

Plate compactors should not be used unless necessary. Roller screeding is preferred using a roller with the appropriate weight and dimensions.

What can go wrong

Plate compaction causes segregation and bleeding of the cement paste into voids.

3

Getting it right

Joints in the concrete slab should not be saw cut after the concrete has set – roll or form them when the concrete is wet.

What can go wrong

Cutting will cause dust to clog the surface.

4

Getting it right

Concrete should not be placed if temperature is likely to be lower than 5°C during seven days following placement.

What can go wrong

Low temperatures will weaken the concrete and reduce its durability.

Grass reinforcement

1

Getting it right

Ensure bedding layer and infill soil is permeable enough and suitable for plants.

What can go wrong

Grass may die or water may pond on surface.



Poor permeability of soil or bedding layer resulting in water ponding on surface and grass dying

2

Getting it right

Infill soil levels should not come up to the top of nearby hard paving/edging. There should be a gap between the soil and top of the reinforcing layer of 5 mm or sufficient to avoid compaction of the soil by traffic.

What can go wrong

Soil becomes compacted and grass or plants die.



Well-constructed system results in good vegetation growth

3

Getting it right

Ensure allowance is made in the laying for expansion (specific expansion joints may be necessary).

What can go wrong

Expansion can cause the pavement surface to lift if tolerances are not provided.



Handy hint

Keep it clean.

Plan to construct the pervious surface as late in the programme as possible.

Do not allow construction traffic on the finished surface unless it has specifically been designed to carry such vehicles. For example, heavy traffic can easily damage some grass reinforcement systems or cause rutting in other surfaces that are designed for car traffic.



Figure 33.4 Mud and dirt from stored plants can clog pervious surface



Figure 33.5 Works kept clean both during and after construction

33.3 GOOD PRACTICE CHECKLISTS

The following lists should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 33.1 Surfaces – subgrade and sub-base checklist ✓

CBR value checked when formation exposed to confirm design value	
Formation is to specified line and level	
Formation permeability has not been reduced by compaction	
Geotextile placed as per design specification with no tears or holes, and lapped correctly between sheets	
Geomembrane (if required) placed as per design specification with no tears or holes, with joints sealed as per design, and penetrations sealed with Top Hats	
Sub-base meets the specification for: • grading • porosity • hardness and durability • permeability	
Sub-base compacted to specified density and depth and is screeded to specified line and level	
Stabilisation layer placed on top of sub-base if necessary	

TABLE 33.2 Modular permeable surfaces checklist ✓

Laying course is at design thickness	
Blocks laid and joints filled and then compacted	
Surface tolerances specified in design have been achieved	
Block pattern is as specified in design	
Edge restraint and block cutting is acceptable and as shown in design (no cut block should be less than one-third of the whole)	
Joints are full of specified jointing material	
Blocks meet requirements of specification	
Surface is clean and free draining	
Runoff from nearby soil areas cannot occur	

TABLE 33.3 Porous asphalt checklist	✓
No evidence of segregation or pooling of binder in delivery truck beds	
Asphalt meets requirements of specification	
Suitable laying machine is used	
Asphalt laid in thickness specified in design (maximum layer thickness and total thickness)	
Asphalt delivered and compacted within temperature specified in design	
Asphalt compacted in accordance with specification and to specified line and level (and correct tolerances)	
Surface is clean and free draining	
Runoff from nearby soil areas cannot occur	

TABLE 33.4 Porous concrete checklist	✓
No evidence of segregation during delivery	
Concrete meets requirements of specification	
Suitable roller screed is used as specified in design	
Concrete laid in thickness specified in design	
Contraction joints are formed by rolling or forming at spacing specified in design	
Surface is clean and free draining	
Runoff from nearby soil areas cannot occur	

TABLE 33.5 Resin-bound gravel checklist	✓
Surface is clean and free draining	
Runoff from nearby soil areas cannot occur	

TABLE 33.6 Grass reinforcement checklist ✓

Reinforcement elements are as specified in design	
Sand or gravel infill as specified in design: • permeability • organic content	
Reinforcement is placed to designed line and level	
Infill is placed to correct depth and is below top of reinforcing elements	
Correct grass or plant mix is used	
Allowance for expansion has been provided	
Surface is clean and free draining	
Runoff from nearby soil areas cannot occur	

CASE STUDY 33.1 Poor sub-base construction

A concrete block permeable pavement was specified to provide part of a SuDS scheme for a small local supermarket. The design responsibility for the structural pavement design was not clear and the SuDS designer relied on advice from a supplier.

After completion, the pavement surface settled unevenly. Investigations showed that this was due to the coarse graded aggregate sub-base layer being placed in one thick layer of 250 mm instead of two separate layers (ie 125 mm thick for each layer). It had then not been compacted properly.

The jointing material was placed at less than half of the specified coverage of 2 kg/m^2. This exacerbated the problems cause by the settlement and allowed the blocks to become loose, which resulted in rutting in heavily trafficked areas.

The responsibility for the design was unclear because the SuDS designer used informal advice from the supplier on structural design. The SuDS designer was not appointed to do the structural design.

Lessons learnt

- Always make it clear who is responsible for the design of a pervious pavement. Do not rely on advice from suppliers unless they are under contract as the designer.
- Provide adequate compaction of the sub-base in thin layers.
- Provide adequate jointing material and top it up after three months of trafficking.

CASE STUDY 33.2

Poor installation and clogging by mud from site traffic

The design for a permeable paving scheme required a 80 mm thick layer of asphalt to be placed over the permeable sub-base, so that the contractor was able to use the asphalt layer for construction traffic. The design required holes to be cored through the asphalt before laying the blocks so that water could get through to the sub-base. The holes were to be in staggered rows.

Following reports of flooding issues within the residential development, the developers commissioned a report to investigate possible causes. It was discovered that joints were blocked with silt, cement and soil, severely reducing their permeability, which was causing the flooding. The asphalt layer was present at the correct thickness and it had been used for site access.

The investigation revealed that holes had been punched through the layer at 500 mm centres in grids rather than staggered rows. It also found that site debris/dirt had not been cleaned off the asphalt surface before coring out the holes. As a result, it was possible for rainwater to run past the holes and collect at low points, as well as dirt from construction traffic clogging them.

Remedial recommendations included taking up all block paving, cleaning off the entire asphalt surface, and ensuring that all cored holes were clean and free from silt. The blocks were re-laid with clean bedding and joint materials.



Figure 33.6 Dense bitumen macadam base course not cleaned before coring, and with holes punched in grids, not staggered rows as specified

Lessons learnt

- The importance of ensuring that works are carried out according to the design and specification, and carrying out site visits to inspect and check the works before the construction is covered up.
- Lay polythene sheeting over completed permeable paving during future works to ensure materials do not block joints.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Infiltration** is the ability of the soil to absorb water.



34 ATTENUATION STORAGE TANKS

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Chapter 34

Attenuation storage tanks

This chapter provides information on the challenges that may arise when constructing attenuation storage tanks and how to avoid them.

- *A construction checklist for attenuation storage tanks is provided in Section 34.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design and construction of attenuation storage tanks can be found in The SuDS Manual (CIRIA C753) Chapter 21.*
- *General information on construction checklists can be found in The SuDS Manual (CIRIA C753) Appendix B6.*

34.1 INTRODUCTION

Attenuation storage tanks are underground tanks or oversize pipes that allow water to be stored temporarily. There are various types of tanks made from different materials. Each product will have different characteristics and strength and they cannot simply be swapped without the approval of the designer (see **Part G Case study 37.2**). If a manufacturer/supplier is giving design advice and taking responsibility for the design they should be employed under contract to provide design services.

These tanks are geotechnical structures and those building them should have been provided with a geotechnical design report prepared by the designer. This provides the key geotechnical design assumptions that have been made about ground conditions. If observed ground conditions are different to those assumed in the design, the designer should be consulted.

34.2 CHALLENGES IN CONSTRUCTING STORAGE TANKS

Attenuation storage

Many of the issues are relevant to all types of attenuation storage regardless of the type of tank.

1

Getting it right

Ensure correct levels are constructed to outfalls.

What can go wrong

Tank may not store enough water or drain down properly.

2

Getting it right

Ensure the soil cover above the tank is in accordance with the levels and depths shown on the design drawings. Where the information is not clear ask the designer for clarification.

What can go wrong

With geocellular tanks in particular, slight changes in the depth of cover can have a big effect on the structural performance of the tank. Both too little and too much soil/fill over the tanks can cause them to collapse.



Subsidence of a car park area caused by collapse of attenuation tank

3

Getting it right

Check the construction depths are correct and are as shown on the design drawings.

What can go wrong

System may collapse because of too great a pressure on the sides from the soil and/or groundwater.



Tank collapse due to excessive earth pressure on side

4

Getting it right

Ensure the specified backfill materials have been used and specified level of compaction has happened.

What can go wrong

Compaction plant that is too heavy may cause the tank to collapse.

Incorrect backfill materials can impose higher loads on the tank causing it to collapse.



Stiff clay backfill with bricks, etc over top of tank has contributed to collapse due to compaction required and unequal loading



Backfill materials chosen, spread and compacted according to specified plan

5

Getting it right

Construction traffic should be prevented from passing over or working above the tank if necessary, especially cranes. Temporary fencing should be provided as necessary.

What can go wrong

Tank may collapse and cause overturning of vehicle or crane.



Crane used during green roof construction with correct spreader plates used to avoid overstressing underlying tank

6

Getting it right

Muddy water should be prevented from entering the tanks.

What can go wrong

Build-up of sediment and debris, which may block the system and/or reduce storage, resulting in flooding. Cleaning out the tanks can be difficult.

7

Getting it right

If products are substituted the designer of the tank should be consulted to make sure the alternatives are acceptable.

What can go wrong

Each product has different strength characteristics, maintenance requirements and durability.

Substitution could result in a lower strength unit being used with the potential for collapse or the maintenance could be more difficult or frequent or the design life may be reduced.

8

Getting it right

Correct membranes and geotextiles should be used as specified on design drawings. Ensure correct sealing and jointing methods are used as specified (eg use welded joints rather than taped joints that cannot withstand hydrostatic pressure). Use pre-formed corners and details if necessary.

What can go wrong

Incorrect membrane or sealing will lead to leaks in the tank. Incorrect geotextile could lead to soil migration and/or clogging of tank or collapse of overlying or adjacent soils.



Tape from DIY store used to seal geomembrane instead of welding, leading to leaks

9

Getting it right

Ensure the bottom of the excavation is firm and provides adequate support to the tank or pipe.

What can go wrong

Uneven base can lead to inconsistent loading on the tank. This may cause the strength of the tank to be exceeded and subsequent collapse.



Inadequate formation – poor groundwater control results in difficult excavation and uneven formation

Geocellular systems

The challenges listed here are specific to constructing geocellular tanks.

1

Getting it right

Ensure excavations are kept dry during construction to prevent the tank floating. These structures are lightweight and can float in a few millimetres of water.

What can go wrong

Flotation of the tank can cause damage to the tank and lining requiring repair.



Tank has floated and moved out of line because of rainwater collecting in the excavation placing stress on liner and units

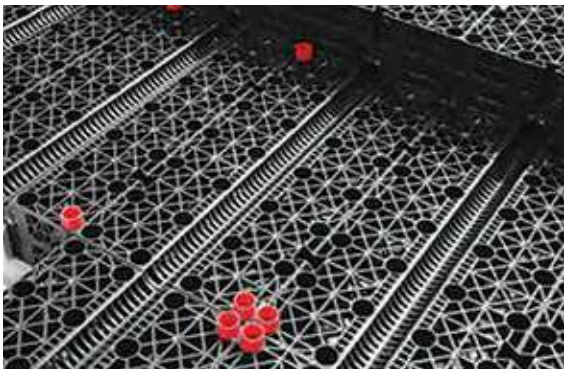
2

Getting it right

Ensure correct connectors are used as specified between layers and between tanks at rate specified in design.

What can go wrong

The individual units can move and place excessive stress on adjacent units, which can cause collapse.



Vertical shear connectors to join layers



Horizontal ties or clips

3

Getting it right

Ensure flat-packed or partly assembled ‘nested’ units are correctly assembled on site following manufacturer’s instructions.

What can go wrong

Incorrect assembly can lead to collapse of tank.

Plastic corrugated arches

This issue is specific to constructing tanks using plastic corrugated arches.

1

Getting it right

Backfill is brought up evenly on both sides of the arch.

What can go wrong

Uneven filling can cause unacceptable stress in the arches and collapse.



Backfilling around arches



Handy hint

BBA certificates, CE marking and other certification schemes do not guarantee that a product is suitable for every site. They are only intended to help people understand the potential performance of a product and/or that suitable quality assurance is in place during manufacture. For example, the performance of a product can be stated in terms of strength over a specified design life. Certification establishes the technical performance of a product for specified loading conditions.

The required performance on a particular site depends on where and how it is going to be used (depth, traffic loads etc). The designer of the drainage system will need to assess whether the level of performance stated in the certificate satisfies the loading conditions that apply to the project in question. A certificate is not a guarantee that a particular product is appropriate in a defined situation. Design calculations are still required and should be checked rigorously.

The certificate should be read carefully, especially with regard to design life and limitations on the applications covered by the certificate. It is often wrongly believed that BBA certification of products is required to comply with building regulations or to gain building control approval. This is not the case.

Oversize pipes (of any material)

The following may apply to both plastic and concrete oversize pipes.

1

Getting it right

The bedding layer should be even below the pipe and there are no hard spots.

What can go wrong

Uneven bedding can increase load on pipes and cause movement or cracking. This is especially important with plastic pipes due to their fragility.



Preparing bedding layer for pipe

2

Getting it right

Ensure the correct seals are used and installed to specification.

What can go wrong

Poorly sealed pipes may leak.



Lubricating seal before assembly

Corrugated steel pipes

The following challenge can occur when using corrugated steel pipes.

1

Getting it right

Backfill should be even on both sides of the pipe.

What can go wrong

Uneven filling can cause unacceptable stress in the pipe and collapse.



Backfilling evenly around pipes on each side

CASE STUDY 34.1

Inadequate formation for geocellular tank

A geocellular tank was installed by a general groundworks contractor who did not have experience of this type of construction. The formation was not excavated to the tolerances specified by the tank supplier and had excessive undulations.

The tank was constructed on the formation and after a few weeks the overlying concrete pavement started to crack. The undulating formation resulted in large voids below the tanks that allowed excessive movement up and down when vehicles passed over above. Consequently, the tank and concrete slabs had to be broken out and reconstructed.

Lessons learnt

- Ensure formation is to specified tolerances so that undulations do not cause excessive movement or leaning of stacked units in the tank.

CASE STUDY 34.2

Ignoring design and manufacturer's installation guidance

A geocellular tank was to be constructed below a road with the edges of the tank parallel to the road kerb line (which had a slight curve). The tank was installed by a general groundworks contractor with no previous experience of this type of construction. The contractor did not check with the designer or the supplier and made the decision to install the geocellular units on their sides as 'curving' the tank to follow the kerb line was easier. The error was only realised when installation images were supplied to the manufacturer for marketing purposes. The units had a lower strength on the lateral or side face and so would not be able to support the vertical loads if laid on their sides. The contractor was informed that the structure would have to be rebuilt by which time it had been backfilled and the surfacing laid. This resulted in extensive remediation works.

Lessons learnt

- Ensure manufacturers' installation guidelines are followed and seek clarification if unsure.
- Inspect tank construction before covering over and backfilling.

CASE STUDY 34.3

Effective backfilling of a geocellular tank

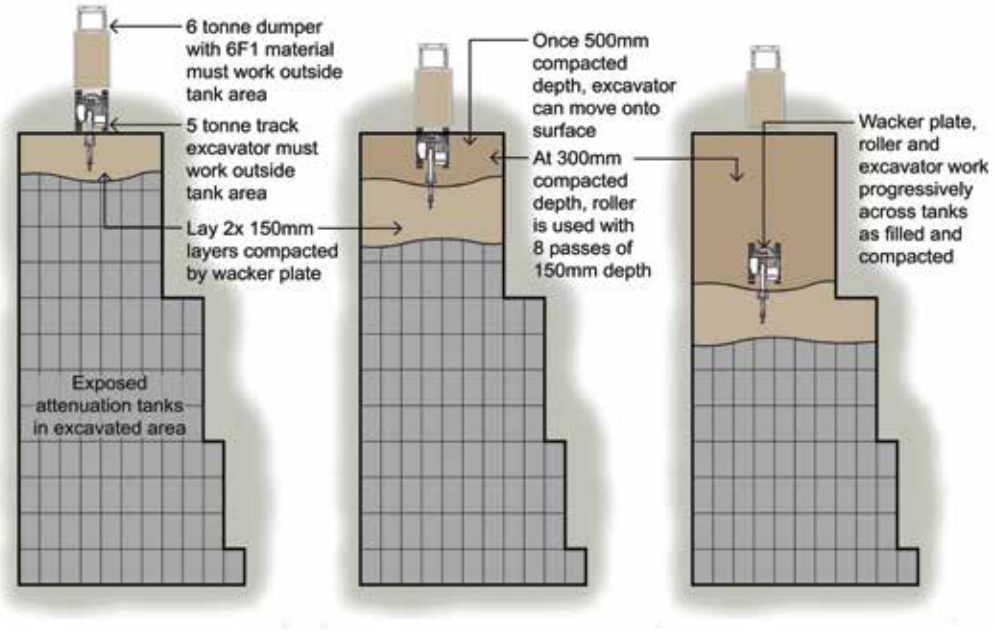


Figure 34.1 Plan view showing machinery access staged to relate to the depth of compacted backfill laid



Note the wacker plate seen on thinner layered areas (less than 300 mm), excavator on thicker areas (500 mm+), and the dumper truck off tank completely

Figure 34.2 Build-up of layers of backfill

A geocellular tank was specified within a large-scale project. The supplier had recommended procedures for backfilling the tank. These were necessary to prevent overloading or damage to the tank by the excavator and compaction plant. The contractor developed a detailed method statement for backfilling over the tank. The following sequence was followed:

1 150 mm layers of backfill laid onto the tank from a position outside of it (by end tipping/placement with excavator) and compacted by wacker plates.

2 When 300 mm depth of backfill over the top of the tank was reached, a roller compactor was used with eight passes on 150 mm thick layers.

3 When 500 mm depth of backfill over the tank was reached, a tracked excavator could access the surface.

It was important that dumper trucks or other heavy machinery were not allowed access to the tank surface.

Lessons learnt

- A thorough understanding of the loading problems and manufacturer's installation guidance, allowed an appropriate plan for filling over the tanks to be developed, which would not overload or damage them.

34.3 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 34.1 Attenuation storage tanks checklist ✓

Formation is to correct depth and level shown on design drawings	
Side slopes to excavation and ground conditions are as assumed in the geotechnical design report	
Base of excavation is level and firm	
Tank units are as specified and shown on design drawings (make sure correct classification or strength units have been delivered)	
Correct number and location of connecting units used and flat packed units assembled correctly	
Correct geotextile or geomembrane is as shown on design drawings, including the protection fleece if specified	
Backfill is as shown on design drawings and as specified	
Compaction of backfill with plant is as specified by the designer (ie not too heavy)	
Backfill over top of tank to depths is specified on design drawings and in the specification	
Backfill is compacted with correct plant and to the required density	
Tank is fenced off to prevent overloading by construction traffic (if necessary)	
At pre-handover inspection of tank, it should be free of silt and other debris (CCTV survey may be necessary)	

Jargon buster

- A **British Board of Agrément (BBA) Certificate** is a document that shows the fitness for the purpose of a construction product and its compliance or contribution to compliance with the various Building Regulations applying in the UK. BBA certificates are awarded to products that have passed a comprehensive assessment that includes laboratory testing, an on-site evaluation and production inspection. The certificates contain details of the physical properties, limits on application and installation procedures that must be followed.
- A **CE mark** is a symbol that stands for European Conformity. A CE mark on a product is a manufacturer's declaration that the product complies with the requirements of the relevant European standards or legislation for the application (if such standards or legislation exists). CE marking is a self-certification scheme. Manufacturers sometimes refer to products as CE approved, but the mark does not signify approval. A CE mark does not show that a particular product is suitable for a specific design – the design should be based on the properties declared by the manufacturer.
- **Closed-circuit television (CCTV)** is the use of video cameras to transmit a signal to a specific place, on a limited set of monitors (en.wikipedia.org, 2017).



35 DETENTION BASINS

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Chapter 35

Detention basins

This chapter provides information on the challenges that may arise when constructing detention basins and how to avoid them.

- *A construction checklist for detention basins is provided in Section 35.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design and construction of detention basins can be found in The SuDS Manual (CIRIA C753) Chapter 22.*
- *General information on construction checklists can be found in The SuDS Manual (CIRIA C753) Appendix B6.*

35.1 INTRODUCTION

Detention basins are areas of land that are normally dry, but fill with water temporarily when it rains. They can either be part of the normal SuDS flow route (on-line) or act as an overflow (off-line) storage. Both types store water during significant events and discharge it at a controlled rate. Soft basins that are online may completely manage light rain as they will naturally absorb some water. Basins can be soft or covered with hard surfacing (often the case for off-line basins in urban situations). Soft basins are mainly grass, but can also be planted.

Planted or grass detention basins have an important role in providing improvements to runoff water quality. They may also have a layer of engineered soil and/or under-drains across the base to ensure that they dry out as quickly as possible. In some circumstances where infiltration is not desired (such as over contaminated land) they may also be lined. However, most are designed to be attractive useable features that then become components of the drainage system when it rains. Planted detention basins may also contain a small permanent wetland or pond.

Soft detention basins are often used on site to manage temporary site runoff during construction, but should be fully remediated before being permanently planted as part of the SuDS scheme or public open space. Where detention basins are to be lined, reference should be made to **Part F Chapter 33**.



Handy hint

Note that a detention basin may require the appointment of a reservoir engineer if sufficiently large (over 25 000 m^3 held above natural ground levels, as defined in the Reservoirs Act 1975 as amended by Flood and Water Management Act 2010, and in Scotland the Reservoirs (Scotland) Act 2011).



Figure 35.1 Soft landscape detention basin



Figure 35.2 Hard landscape detention basin

35.2 CHALLENGES IN CONSTRUCTING DETENTION BASINS

Detention basins

Most of the challenges arise when constructing detention basins to the sizes and levels as designed, and ensuring that the inlet and outlet levels are correct. Such changes should be referred to the original designer as they are likely to affect the ability of the basin to work as intended.

1

Getting it right

Levels and gradients are constructed as per the design drawings – consult the designer if changes are required.

What can go wrong

May affect capacity of the system to store water and limit its ability to drain causing waterlogging, which may kill grass or planting.



Levels correctly constructed to detention basin

2

Getting it right

Levels of inlet and outlets, and the size of orifices are built as designed. Changes should be agreed with the designer.

What can go wrong

Incorrect inlet/outlet levels may affect both the capacity of the system and the rate/volume of discharge. A larger orifice to the outfall could cause downstream flooding.

Incorrect levels can also cause unsightly silt build up in places or allow preferential flow paths to develop that cause erosion.



In heavy rainfall, the detention basin has filled up to the level of the outlet, fulfilling its intended capacity

Planted detention basins

Challenges arise primarily from potential changes to grading of slopes and levels. These could affect the capacity of the system and its ability to provide water quality improvements, as well as potential changes to the visual quality and usability of the open space.

1

Getting it right

Base level gradient is even and no greater than 1 in 100. Levels/gradients should not be changed without agreement from the designer.

What can go wrong

Water may pond on the base if gradients are insufficient reducing its usability/amenity value. If the slope is too great, erosion may occur.



Uneven gradients causing ponding of water that has killed the grass

2

Getting it right

Changes in levels or excess fill material does not alter bank gradients to an unacceptable degree.

What can go wrong

Gradients may become unsafe when the basin contains water and ideally no steeper than 1 in 3. Steep slopes may also become difficult to mow/ manage and visually unacceptable as open space that is intended to be used for recreation.



Unacceptably steep bank grading for management, safety and visibility

3

Getting it right

Location of inlets and outlets for planted systems should be built as designed (to ensure maximum flow length through the basin). Changes should be agreed with the designer.

What can go wrong

If inlets and outlets are placed too close together the value for both storage and improvements to water quality will be reduced.



Inlet and outlet too close together (and their function completely misunderstood)

4

Getting it right

Manage site runoff to ensure that the basin does not fill before completion.

What can go wrong

If unexpected water enters the system it may cause significant health and safety risks for site operatives.

It is more difficult to establish grass cover once the system is online.

5

Getting it right

Ensure good vegetation cover is established before water enters the system to prevent erosion and to ensure improved water quality.

What can go wrong

Poorly-established vegetation may create erosion and silt deposition within the basin. Water may exit the system still poorly treated.



Mature vegetation within detention basin

35.3 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 35.1 Detention basins checklist ✓

Completed levels agree with original design drawings (if not, see next item)	
Audit trail of changes to ensure revised scheme still fulfills requirements of the original scheme	
Location, sizing and level of inlets and outlets are as design drawings	
Level of base to planted basin is consistent and no >1 in 100	
Where engineered soils are used to provide infiltration, check delivered soils comply with specification	
Seed/turf mix complies with the original specification	
The species and size of planting has not been changed (refer to the designer for suitability)	
Vegetation is sufficiently dense to withstand water flow without eroding before bringing into use	

CASE STUDY 35.1 Incorrect side slopes

A detention basin was designed by a team of engineers and landscape architects. The basin was part of a large SuDS scheme for a warehouse development. The basin was integrated into the landscape and had shallow side slopes that did not exceed 1 in 3. This was to meet the client's requirements for health and safety on the site. The designers were not involved with the construction of the basin.

The contractor redesigned the drainage including the basin to reduced costs. The revised basin had 1 in 2 side slopes. On completion of construction the client asked for a health and safety audit of the basin. This raised the issue of the 1 in 2 side slopes. The client referred to the original designer who would not approve the steeper slopes. Remedial works had to be completed including further excavation to provide shallower slopes.

Lessons learnt

- Ensure that any changes in design during construction meet the requirements of the original design brief.



36 PONDS AND WETLANDS

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Chapter

36

Ponds and wetlands

This chapter provides information on the challenges that may arise when constructing ponds and wetlands and how to avoid them.

- *A construction checklist for ponds and wetlands is provided in Section 36.3.*
- *General construction checklists are provided in Appendix A1.*
- *Detailed guidance on the design and construction of ponds and wetlands can be found in The SuDS Manual (CIRIA C753) Chapter 23.*
- *For general information on construction checklists see The SuDS Manual (CIRIA C753) Appendix B6.*

36.1 INTRODUCTION

Ponds and wetlands are SuDS components that have a permanent pool of water. While ponds have a varying water depth of (generally) up to 1.5 m, wetlands are shallow components, with large areas that either have a minimal level of water or are damp rather than wet, unless actively storing water. Wetlands are mainly covered in vegetation, while ponds are mainly water, with planting around the edges.

Ponds have two purposes:

1 Store large volumes of water temporarily, as they are generally located towards the lower part of a site and at the end of the drainage system (or management train).

2 Provide major water quality improvements, as water slowly passes through their vegetation.

Wetlands are often used to provide water quality improvements. The construction and planting of these components should maximise the time taken for water to pass through them to allow treatment of pollution to occur. Where the pond or wetland is to provide attenuation storage, the storage level is set at a point above the normal day to day water level. When it rains the water level in the pond or wetland rises up to the storage level.

The inlet should be constructed to remove remaining sediments in the runoff, and the outlet structure should regulate flows downstream to the designed/permitted flow rates and volumes. A route for exceedance flows in extreme rainfall events should be provided. Ponds will always be lined, unless constructed in an area with clay soils that have been confirmed as suitable to retain the water. The liner may be a range of materials including butyl rubber, bentonite sheeting or clay.

Ponds and wetlands are important for biodiversity, and so they require a variety of carefully-designed bank gradients and levels above and below the water line to provide a wide range of habitats. Planting and shallow banks are also key features in making ponds easy to maintain, and as safe as possible in public places. Constructing an attractive, high-quality pond or wetland is fundamental to its acceptability by the public where included within public open space. Changes to bank slopes and planting etc should not be made without consulting the designer.



Figure 36.1 SuDS pond in urban area, Sweden



Figure 36.2 Small urban wetland



Figure 36.3 Large-scale wetland



Handy hint

Note that a basin may require the appointment of a reservoir engineer if sufficiently large (over 25 000 m^3 held above natural ground levels – Reservoirs Act 1975 as amended by Flood and Water Management Act 2010, in Scotland the Reservoirs (Scotland) Act 2011).

36.2 CHALLENGES IN CONSTRUCTING PONDS AND WETLANDS

Ponds and wetlands during construction

When constructing ponds and wetlands, challenges can arise when ensuring the layout, depths and bank gradients are as designed, with the appropriate inlets and outlets set at the correct levels to ensure the system has the correct capacity and functions as designed.

1

Getting it right

The area intended for ponds or wetlands is not used for construction runoff (unless fully remediated before construction).

What can go wrong

Existing site vegetation (intended for retention) may be killed by construction site runoff. Polluted runoff may contaminate existing soils making them unsuitable for planting, requiring their removal and replacement or remediation.



Pond used for site drainage requires full remediation before planting and handover

2

Getting it right

Levels/depth to base, shelves, and banks of pond/ wetland are as designed and specified.

What can go wrong

May not store enough water or provide proper planting/ biodiversity areas.



Broad shallow basin with gently sloping sides

3

Getting it right

Side slopes are graded as designed.

What can go wrong

Side slopes that are too steep will cause problems with plant establishment, maintenance or safety and may change the storage capacity.



Level area mid-slope to allow for safe maintenance operation

4

Getting it right

The inlet system includes a sediment trap/forebay to reduce velocity of flows and enable sediment to settle before entering pond/wetland. Check with designer for reasons if not included.

What can go wrong

Lack of forebay may create erosion, scouring, reduction in pollution removal function, and sediment carried into downstream system. Pond will have poor quality and amenity value, and will be difficult to improve in the long term.



Pond basin siltation due to no forebay or pre-treatment before entering pond

5

Getting it right

Construction detailing of inlets and outlets is visually acceptable.

What can go wrong

Poor aesthetics has an adverse effect on amenity value, undermines public acceptability of SuDS, and is a potential safety risk.



Imposing and unattractive concrete structure and barriers around outlet

6

Getting it right

Inlets and outlets are constructed to protect from blocking and to regulate flows to permitted discharge rates.

What can go wrong

Blockages or excess volumes can cause downstream flooding.



Outlet blocked with silt, turf and litter

7

Getting it right

Site runoff is managed to ensure the component does not fill before completion.

What can go wrong

Unexpected site runoff may cause significant health and safety issues for site operatives.



Balancing pond remains empty before completion

8

Getting it right

Expert guidance is sought on how to manage natural regeneration of planting (if used).

What can go wrong

Insufficient growth of planting can lead to scouring and erosion. The pond banks/wetland may become covered in unwanted invasive plant species. May become colonised by unwanted/protected species.



Invasive pond weed dominating within pond

9

Getting it right

Grass and planting has been established before use.

What can go wrong

Poorly-established grass and planting may cause erosion of soil, with sediments being washed down the system and potentially causing blockages elsewhere.



Pond in use before establishment of vegetation, will make good growth difficult to achieve

10

Getting it right

Mulches are not specified as loose materials anywhere within areas likely to be wet unless checked with the designer.

What can go wrong

Loose mulches may block overflows and can be washed down the system by surface runoff.

11

Getting it right

Safe exceedance flow routes and freeboard to the pond/wetland are constructed to the levels as specified.

What can go wrong

Lack of exceedance flows routes and freeboard may result in overtopping of pond/wetland with risk of unplanned flooding of nearby land/properties and damage to banks.

Lined ponds and wetlands

Installing liners correctly is vital to ensure they are watertight, but the following issues will need to be addressed for geomembrane liners, and for sheet butyl and bentonite liners to protect them from damaged as part of the construction process.

1

Getting it right

Check that formation for geomembrane liner is free of sharp stones or other material before laying protective fleece and liner.

What can go wrong

Liner can be punctured if sharp stones or other material is not removed before laying.



Punctured geomembrane and geotextile due to sharp materials underneath

2

Getting it right

Laps on liner are sufficient and sealed in accordance with manufacturer's instructions.

What can go wrong

Liner can leak if laps are not sealed correctly.



Sealing of geomembrane laps

3

Getting it right

Liner is covered by a protective layer either below or above the liner (or both) as specified.

What can go wrong

Liner can be punctured or degrade due to exposure to UV light and exposed liners look unattractive.

4

Getting it right

Operate machinery from outside the pond once it is lined.

What can go wrong

Liner can be damaged.

Puddle-clay lined ponds and wetlands

The issues arise mainly from ensuring that the right consistency and thickness of clay is used, and that it is adequately puddled to achieve a water-retaining layer. Once laid, the clay should be protected from drying out before the water filling the system.

1

Getting it right

Clay is of an appropriate mix as specified, and puddled to specified thickness and consistency.

What can go wrong

Liner can leak.

2

Getting it right

Clay lining is protected during hot/dry weather before covering with soil/filling with water.

What can go wrong

Clay can crack and liner can leak.

36.3 GOOD PRACTICE CHECKLIST

The following list should be used as the basis for on-site checks, but should be amended to suit the specific requirements of the site and SuDS component specification.

TABLE 36.1 Ponds and wetlands checklist ✓

Land used for temporary site runoff – fully remediated before construction of pond/wetland	
Plan dimensions, depths and levels throughout ensuring inlets and outlets agree with original design drawings	
Audit trail of changes to ensure revised scheme still fulfils requirements of the original scheme	
Size of area drained has not increased from that specified or designed	
Banks and benches are constructed to widths and gradients specified	

TABLE 36.1 Ponds and wetlands checklist (contd) ✓

Liners are installed, sealed and protected as specified	
Inlets control water velocity to provide slower flows and provide forebays for sediment where specified	
Inlets and outlets are protected from blockage by debris and silt build-up	
Plants and species are supplied to size/form as specified before planting	
Plants set out and planted in accordance with the specification	
Agree how successful natural regeneration is to be approved, and agree supplementary planting/ change to management approach	
Agree remediation measures for areas of erosion	

CASE STUDY 36.1 Allowing time for establishment of planting



Figure 36.4 Sewage fungus growing within wetland

A large-scale SuDS scheme involved converting existing playing fields into a large wetland. To achieve this, the outlets from two surface water culverts were diverted into the wetlands. The scheme was constructed in summer 2015. However, by the end of 2015, sewage fungus was growing within the wetlands, especially near the culvert outlets (or inlets to the wetland). Reed establishment was also limited at these locations. The spread of fungus was relatively contained, which led to the conclusion that it was caused by the more polluted water at the entrance to the wetland.

This issue was solved without intervention purely allowing time for the establishment of the vegetation. This resulted in an improved water treatment capability, which cleaned up the wetlands. The wetland is now functioning well and as designed.

Lessons learnt

- The need to allow time for the proper establishment of wetlands to enable them to function to their full capability.

Jargon buster

- A **component** is a drainage feature that can take many different forms.
- **Exceedance flow** is the flow of water that overflows from the top of the SuDS when the rainfall is greater than the designed volume of the system.

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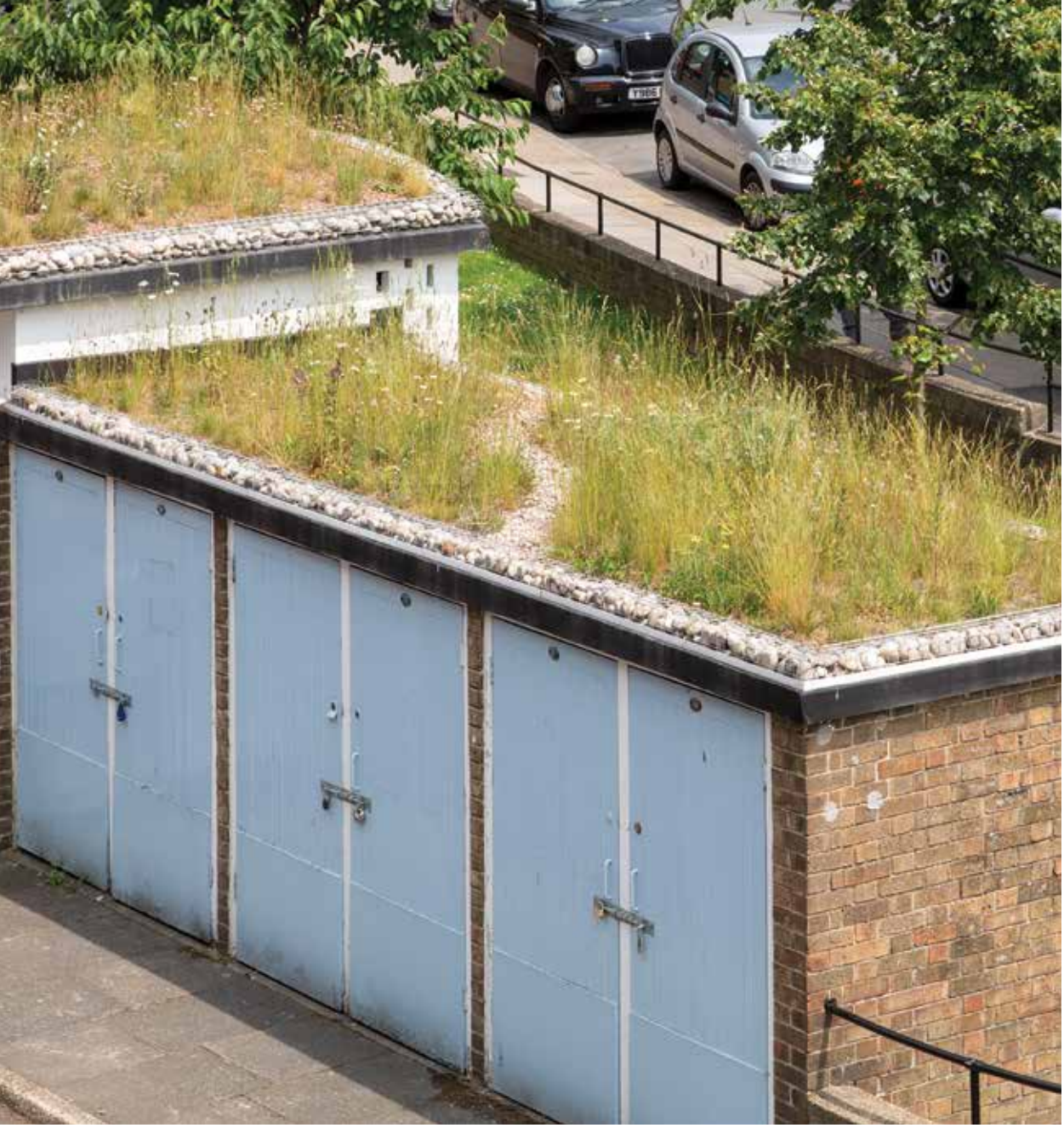
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Chapter

37

Case studies

This chapter provides case studies that give an overview of large-scale SuDS construction projects, incorporating multiple SuDS components.

CASE STUDY 37.1 **Sustainable industries park, Dagenham**



Figure 37.1 Completed pond within industrial park



Figure 37.2 Swale formed with coir walls

The aim of this project was to develop a large-scale industrial park that would accommodate sustainable technologies, both in the businesses located there, and through the integration of sustainable measures such as a district heating scheme in its construction. The Greater London Authority (the client), also wanted the park's landscape concept to embrace a sustainable philosophy. So, the designers conceived the industrial park as a wood, within which various industrial units would be set. This would create a simple, but robust natural landscape to accommodate buildings, people and SuDS alongside its developing ecology.

Convincing the development team the SuDS design would work

The SuDS concept was to be delivered by a system of swales linked to a series of ponds. Hard-surfaced areas were to drain into the swales by 'over the edge' drainage. Detailed design drawings and an explanation of the design concept were provided. However, despite the simplicity of the concept, the project manager and development team found it difficult to understand/believe that such a system could accommodate the necessary drainage capacity, and continually questioned whether the original design would work. It was only through the insistence of the client who had positively supported this design approach for their sustainability park, that the scheme was confirmed for construction on site.

CASE STUDY 37.1 **Sustainable industries park, Dagenham (contd)**



Figure 37.3 Hard channel section within route of swale



Figure 37.4 'Dragons teeth' rocks

Familiarity with SuDS construction requirements

During on-site construction there were continual queries from the contractor, who was unused to constructing roads or roundabouts without kerbs, and who needed ongoing reassurance that the details as drawn were correct. However, as a traditionally procured contract with a full set of Bills of Quantity, the contractor was keen to construct the works as drawn, rather than seek to vary them, which helped to reinforce the importance of delivering the design as conceived.

Issues with translating 'artistic' design practically on site

Once these initial problems had been worked through, a productive working relationship developed, which was particularly useful when the decoratively arranged sandstone rockwork around corners of the road was misinterpreted. Incorrect sizes and proportions were used and were installed more like a series of dragon's teeth than naturalistically. These had to be re-arranged to meet the design intent. However, once this intent was clear, the rest of the rockwork was successfully installed.

Lessons learnt

- Ensuring that the client team is engaged in the SuDS design concept from the beginning, so that it has their support throughout.
- The importance of retaining the original design team to ensure that the original design concept is delivered on site.
- The importance of good communications between the designer and contractor at all stages of the process from construction planning through to completion.

Civil engineering and SuDS designer	Civic Engineers
Client	Greater London Authority
Client representative	Turner and Townsend
Main contractor	Volker Fitzpatrick
Principle architect	Sergison Bates

CASE STUDY 37.2 Highways upgrade, A1 Leeming to Barton



Figure 37.5 Baldersby East and West Ponds visible, highlighting forebay with reeds and secondary dry retention storage area, Junction 50 A1(M)



Figure 37.6 Attenuation pond with reed planted forebay



Figure 37.7 Base of detention basin

A large-scale, two-phase project to upgrade a 12-mile stretch of the A1(M) from an existing dual carriageway to a three-lane motorway. This included the construction of new and improved local roads incorporating SuDS components within the design, which formed Phase 2 of the project.

The SuDS components were integrated with a mix of traditional drainage components (trapped gullies, catchpits, filter drains, French drains and petrol/oil interceptors) to collect water and filter pollutants deposited by traffic. Flow controls and attenuation facilities were provided to reduce the effect of downstream flooding by the use of ponds, offline storage structures and online storage. Cut-off valves downstream of all outfalls and upstream of ponds were also installed to contain pollutants in the event of a significant spillage, for example to cope if a fuel tanker is involved in an accident.

The section of the A1(M) being upgraded was close to several RAF air bases who expressed concerns about the risk of wild fowl strikes due to the proposed expanses of open water.

To overcome this, the attenuation ponds were designed as two-stage ponds. The first stage was a wet forebay pond planted with reeds to mask the permanent water and discourage flocks of birds, which also had a secondary benefit of dealing with residual pollutants off the carriageway that pass through the first stage of treatment in the filter drains etc. The second stage was a detention basin to provide attenuation, enabling the discharge to be restricted into the downstream watercourse/ditch.

Issues encountered on the project during construction included:

- The project-wide earthworks sequencing and traffic management issues directed the construction programme of the attenuation areas. Earth movement was well planned by a full-time earthworks manager enabling most the attenuation ponds to be created in the early phases of construction with cut and fill balanced to limit multiple handling of the material.
- High groundwater table and flotation of geotextiles was a considerable problem in some areas – all ponds needed an impermeable liner one metre below the bed, with one pond where the water table had artesian pressure requiring the membrane to be buried eight metres deep. A pressure relief system was adopted at some of the ponds to reduce the depth of excavation required.
- One of the attenuation ponds was re-designed to alleviate the impact on a fault line reducing the risk of artesian pressure.
- Nesting birds during pond construction were an issue, and highlighted the need to consider timing of the nesting season to limit its impact.

CASE STUDY 37.2 **Highways upgrade, A1 Leeming to Barton (contd)**

- Non-acceptance of geocellular storage units on local authority-adopted parts of the scheme meant a corrugated steel pipe storage system had to be substituted. This had implications on outturn cost and design issues in accommodating the maintenance access requirements.
- Filter drains were installed as a value engineered replacement of conventional concrete v-channels. This left a residual risk of difficulties in installing a nearby safety barrier due to reduced lateral support to the barrier posts.

Given the scale of earthworks required on the highway, construction of the SuDS was not viewed as an onerous task and allowed good soil to be used along the highway construction and poor soils to be used in the ponds. One pond was partially constructed before the start of the highways earthworks so that it could accommodate the discharge of surface water, which was in line with good practice. Sedimentation of the ponds was limited using straw bales, sediment entrapment mats, silt fences, and grass filter strips.

Lessons learnt

- Frequent dialogue with Highways England, the Environment Agency and the local authority throughout eased the approvals process.
- Phase 1 reeds planted 4/m^2. This led to overcrowding, and was reduced to 1/m^2 for Phase 2.
- The original design of the outfall from the forebay pond was susceptible to clogging by dead reeds. This was re-designed with 40 mm stone and a filter drain, which has proved better. Tests were carried out to select the most suitable length of filter drain pipe to achieve the desired drainage rate for each pond. This detail was found to remain susceptible to clogging, so a five metre buffer strip around the filter drain was also put in place.
- Cellular storage, which was used in areas not adopted by the local authority, was acceptable to Highways England, but because of the available space and ground conditions, had to be constructed in a temporary sheet piled strutted coffer dam making access difficult. The access around the edges was a particular problem as the struts caused an obstruction. The tanks were provided with a double geomembrane liner to reduce the risk of leakage in or out. This was due to high groundwater levels and to prevent pollution from the construction process reaching a local aquifer.
- Where not draining the highway (draining embankments etc) it was possible to drain directly to French drains.
- Significant biodiversity benefits have developed as part of the scheme. However, the ponds were designed to discourage newts (largely on ponds with pre-construction functionality) during the construction phase.
- An opportunity to work with the Environment Agency on flood risk and drainage in the Brough Beck area led to wider flood mitigation measures, which will mitigate the impact of flooding for the Catterick village area.
- Value engineering of drainage items should consider the effect (and cost) on other parts of the development construction.

Client	Highways Agency
Contractor	Carillion Morgan Sindall JV
Principal designers	AECOM and SWECO
Client for local access roads	North Yorkshire County Council

CASE STUDY 37.3

Hammersmith and Fulham social housing SuDS retrofit



Before | After



Before | After

Figure 37.8 Queen Caroline Estate, Hammersmith and Fulham (courtesy Hammersmith and Fulham Council)

Groundwork and Hammersmith and Fulham Council worked together to demonstrate how retrofitting SuDS by including them in proposed open space improvements on housing estates can be a cost-effective solution to improving London's resilience to climate change. A key part of this project was the provision of SuDS to relieve existing problems of localised surface water flooding, as well as improving general sewer capacity issues across the borough. However, it was equally important to demonstrate how a wide range of other benefits such as improved aesthetics and biodiversity, localised cooling/shading, new play opportunities and better air quality could be achieved. This has also improved local social cohesion, while boosting local residents' pride in their estate.

Works began in 2014 on three housing estates with extensive landscape works incorporating SuDS components such as swales, rain gardens and bio-retention basins. A large-scale green roof was installed on one residential building, which was tied in with planned roof maintenance to achieve cost efficiencies, as well as small-scale green roofs on various outbuildings, eg bin stores.

Landscape maintenance is already required for the sites and so they are roughly 'maintenance-neutral'. Where tarmac has been replaced by gardens that require maintenance, they have been offset by turning grass areas to meadow, with simple low-maintenance plant mixes that suit the conditions and provide colour for residents.

The improvements delivered across the three sites include:

- 4500 m^2 of new landscaped areas
- 2600 m^2 of new and improved green infrastructure
- 450 m^2 of green roofs
- surface water from 3200 m^2 of impermeable surfacing diverted away from the combined sewer into green infrastructure (about 1.3 m litres for 12 month period from June 2015)
- 16 per cent increase in permeable surfaces
- 17 per cent increase in vegetation cover.

Generally, the project went quite smoothly, and while there were many challenges, they were mainly around unforeseen services, misunderstanding of some SuDS details, and typical problems of working on a tight urban site. However, all the issues were relatively small scale, with a high-quality finish achieved overall by completion. Key to successful delivery was the good relationship established

CASE STUDY 37.3 **Hammersmith and Fulham social housing SuDS retrofit (contd)**

between the contractors, Groundwork and the estates' residents. The contractors were new to SuDS construction, but had many years' experience of delivering hard and soft landscape works on dense urban housing estates.

Services constraints

The SuDS components had been difficult to integrate within the design, as the site was constrained by services. Full topographic surveys were undertaken along with below ground radar surveys to locate existing services as well as consulting all existing plans that were available. However, despite these surveys, not all services were picked up and in some instances they were found to be on a slightly different alignment or at a different depth to that recorded. This meant that the designs had to be adapted on site (although not substantially). In one example a linear basin along the side of one building had to be shortened due to unmarked services being identified at one end of the component.

In another location two down pipes from a building roof were disconnected with water re-directed into a linear basin running the length of the building. During excavation works for the basin, a surface water pipe was unexpectedly found cutting across the middle of it. Although, it was suspected that the pipe conveyed water from the roof and balconies of the building and had been previously disconnected, the decision was to take the safest course of action and leave it in situ. Fortunately, there was spare capacity within the design, so the scheme was changed on site to incorporate an earth bridge section with the two halves of the now-divided basin connected with a short length of drainage pipe.

Triangular-shaped rain gardens were provided at another location and the depths and alignments of services differed between the radar survey results and what was found on excavation. A shallow telecoms cable was also found that had not shown up on the survey. Consequently, the design had to be adjusted on site, with about one-third of the planting area being replaced with resin-bound gravel surfacing to maintain hard cover over the surfaces as required by the utility company.

Lessons learnt

- Expect the unexpected when excavating near services as the locations may not be as shown even where service scans have been undertaken. Understand that the scheme may need to be adjusted on the ground.
- The importance of consulting the original SuDS designer to agree how the scheme may be amended to retain the same design intent for all aspects (eg quality, quantity, amenity and biodiversity).

Establishing planting, public perceptions and understanding

Across all three estates, green roofs were retrofitted on the roofs of various bin stores and pram sheds. A structural survey was undertaken to confirm the allowable 'greening load' and the suitability of the existing waterproofing was assessed. It was decided to replace the waterproofing to guard against failure that might be unfairly attributed to the green roof, and a shallow (80 mm to 120 mm) green roof build up was designed that could be accommodated by the existing building structure.

Two different techniques were employed to support the safe handling of bulk materials during installation. At one estate where vehicle access was restricted, the contractor used mobile scaffold towers (at additional cost as this was not originally anticipated) to temporarily store and then transfer materials. At the other two sites, vehicle access was available so mobile lifting equipment could be used.

The planting of the green roofs used a mixture of plug-grown plants and seed. Due to wider project programming requirements, the green roofs were planted in April to May, which is slightly later than would have ideally been the case. A series of dry spells during May and June meant that considerably more establishment watering was required. Then in July a prolonged dry spell meant that much of the planting turned brown and died back, raising concerns among residents who had been expecting a colourful summer meadow. Ultimately when it rained, the planting came back and the roofs greened up within a period of a few weeks. Over the next 18 to 20 months the planting browned off twice more, but each time there was a greater understanding among residents of the ability of the plants to bounce back once wetter weather returned.

During the first year there was also a problem with fat hen (a vigorous wild plant/weed) dominating the planting mix. The maintenance contractors were asked to pull them out during their scheduled visits to prevent them becoming too dominant. While some plants had dropped their seed (ideally this would be avoided), they did not return in such large quantities the following year as the sward was better developed, which was more visually acceptable.

CASE STUDY 37.3 **Hammersmith and Fulham social housing SuDS retrofit (contd)**



Figure 37.9 Mobile scaffolding used for roof access



Figure 37.10 Green roof soon after planting

Lessons learnt

- Careful programming of the construction/planting period to avoid the need for extensive establishment watering.
- The need for good communications and managing the residents' expectations about what the scheme would look like and how it would respond during extended dry weather conditions.

Throughout much of the construction process there were significant logistical challenges, particularly around the handling and storage of materials on site, and the management of noise from the works, with some residents, (such as the elderly or unwell), more sensitive to the disturbance than others. Access was a concern, with difficulties getting materials through narrow passageways, and having storage areas immediately next to peoples' homes. Careful planning and ongoing liaison with residents was required. Using the right machinery for the narrow estate roads and constrained sites was important, and restricting the use of residents' parking spaces for site access, accommodation and storage required careful site planning and ongoing discussion between the contractor, contract administrator and residents' representatives. The issues were overcome by the contractors developing good on-site working relationships with the residents, and communicating with residents by attending tenants and residents association meetings inviting resident representatives to meetings before, during and after construction.

Lessons learnt

- Careful planning and communication with residents of materials and waste transport routes and storage areas is important.
- The need for ongoing and effective communications.

Achieving the right construction through inspections

Much of the planting works were carried out by Groundwork's 'green teams', comprising trainees working to develop horticultural skills under the guidance of a supervisor. The green teams typically work on traditional soft landscape works, and occasionally employed methods that although generally considered good practice, can be problematic for SuDS. Examples include soiling up to the level of adjacent surfaces rather than leaving the soil level 50 mm to 75 mm lower to support the flow of runoff into the beds, and mulching the rain garden beds following planting, which risks causing blockages in the overflow pipework if washed off in heavy rain. Throughout the project these issues were rectified and the lessons learnt applied to the next phase of works.

Lessons learnt

- The 'way we usually do it' is not always appropriate for SuDS. With contractors or teams who are inexperienced in building SuDS, greater care is required to ensure that they understand the requirements for the works.

The value of inspections

During the construction of a combined rain garden, tree pit and trench at one location it was not possible to inspect every stage of the build-up (as the component was small so the works progressed quite quickly). This required part of the construction works to be photographaped as evidence to ensure, with an acceptable degree of certainty, that it would deliver the attenuation needed. In some

CASE STUDY 37.3

Hammersmith and Fulham social housing SuDS retrofit (contd)

cases the photographs were from positions or angles that did not allow a full assessment of the works. It is important to agree/confirm photographic requirements, eg location points, before the works begin and then to review these as the works progress to ensure that they remain suitable.

To test the functionality of the SuDS, several components were subjected to storm simulation events, where a pre-determined quantity of water was released into the SuDS components to replicate the designed storm event. In all cases the performance of the components exceeded what was expected.

Lessons learnt

- It is difficult to inspect each stage where a SuDS component is small, and reliance has to be put on good site photographs as evidence for the construction works. Undertaking a storm simulation is a useful way to check that the scheme coped during a measured storm simulation.

Landscape Architect	Groundwork London
Client	London Borough of Hammersmith & Fulham
Project funders	EU LIFE Programme, London Borough of Hammersmith & Fulham, Greater London Authority
Engineering support	Engineering, design and analysis, Environmental Protection Group Ltd
Consultancy support	Green infrastructure consultancy, The Ecology Consultancy
Community engagement	Groundwork London
Contractors	Greatford Garden Services Ltd, Warwick Landscaping Ltd, Organic Roofs, Groundwork London Green Teams, Mitie
Performance monitoring	Sustainability Research Institute (SRI), University of East London

CASE STUDY 37.4

SuDS for Schools project, Wildlife and Wetlands Trust

The Wildlife and Wetlands Trust (WWT) undertook SuDS retrofits on a series of 10 schools, and in doing so it encountered several challenges – some common to most projects, and others specific to individual sites. Some of the issues arose during construction, while some have emerged following completion due to the way the sites are used or managed. Many of the issues arose because the contractors had not built SuDS before and had not properly understood what was required and why, despite having design drawings and a specification that detailed the scheme. However, the projects were all positive experiences, from which both the designers and contractors learned a great deal about SuDS construction.

Queen Elizabeth Girls School

The school is located in a dense urban area and on a steeply sloping site. Challenges initially arose, as the contractor was quite a small company, with limited resources for their existing commitments. This meant that while site visits were planned, the work to be inspected was not always completed when the designer arrived to inspect – sometimes no-one from the contractor turned up on site. As the contractor had never built a SuDS before, this made communications and management of the project on site difficult. Inevitably, they interpreted the works required incorrectly as they did not fully understand how SuDS functioned and what was needed (despite the availability of design drawings). By not understanding the principles of SuDS and the need to slow the flow of water, in one instance, their 'this is how we always do it' approach led to them installing a pipe (thinking it a better solution), than the series of swales and basins that had been designed. However, the contractor was open-minded and keen to understand SuDS construction better, enabling a positive relationship to be developed on site.



Figure 37.11 Variety of shape and slope to optimise habitat development



Figure 37.12 Wetlands becoming established

In this area, the site sloped by nearly 15 m, and as it was a long site, it had a series of five detention swales of various sizes, with check dams, and two bridges and access paths to take surface water from an area of tarmac to create a range of new habitats. The whole layout was around 300 m long. The first problem arose with the swale being excavated as a steep-sided ditch around one metre wide and one metre deep, rather than a shallow swale as designed. The check dams were designed in some locations as a semi-circular arrangement of shallowly stepped sand bags filled with concrete, which allowed water to flow gently over a broad area. However, this was interpreted on site as a low vertical headwall, which also looked ugly when completed. The third issue was on a particularly steep part of the site, where the contractor was concerned that the grass would erode with the passage of water, so decided to pipe it. After some discussion, this course of action was reversed and the original component built instead.

The inspecting designer consequently had to spend much time on site (although this was always intended, as building SuDS was a 'first' for the WWT), to ensure that those building the SuDS fully understood what was required at every step, as those with whom it had been discussed were not site based. While it was possible to re-grade the swale to acceptable gradients, and remove the pipework, the headwall was left *in situ*, as ultimately that section of swale contained reeds. This unattractive feature was visually 'lost' when the vegetation established properly.

CASE STUDY 37.4

SuDS for Schools project, Wildlife and Wetlands Trust (contd)

The design involved a series of temporary and permanent wetlands, and a quite extensive soil investigation had been undertaken at the design stage (a series of augered holes, not a full water permeability test) to check its permeability. However, once on site, one of the locations for a permanent wetland was found to be mainly located on an area of coarse gravel, which was highly permeable. This was discussed on site, and the location of the wetland adjusted to ensure it was fully located within an area of clay soils. Over two years a series of either scrapes and wetland pools were created, that provided a wide range of different habitats, with the planting naturally adapting to the ground conditions and water regime provided.



Note that some cells are dry as a result of highly-permeable soil being encountered, which was missed during initial soil surveys.

Figure 37.13 Wetland complex featuring several detention and retention wetlands before planting

Lessons learnt

- The need to ensure that those building the works on the ground understand the principles behind how SuDS work, and the reasons why it has been designed as it has. Within a company those more senior may understand the concept, but this does not mean that those on site are similarly knowledgeable.
- Make it clear that deviations from the design drawings should be agreed in advance – 'the way we always do it' may not be appropriate when building SuDS.
- Inspections and hold points are clearly identified in advance.
- While permeability tests should be undertaken in advance, be aware that the location may not be typical of the entire area, so consider how extensive these tests need to be.

Planting in the primary schools

Generally, the design for each school was developed with input from the school children, and while this was anticipated, it was not expected that the planting would be undertaken by some of the youngest pupils who were four to five year olds when 10 to 11 year olds had been expected. Consequently, the planting and seeding had to be (sensitively) remediated outside school hours where it became trampled or was improperly planted by the children – this area of work was excluded from the works contract.

Lessons learnt

- Bear in mind the potential need for remediation and close supervision when working with volunteers (regardless of age).



Handy hint

Mix seed with sand to see where the children/volunteers have seeded, and locate the areas they may have missed – and the seed mix will also go further.

CASE STUDY 37.4

SuDS for Schools project, Wildlife and Wetlands Trust (contd)

Susi Earnshaw Theatre School, Chipping Barnet, London

This was a small site, where the SuDS had to be tightly designed into the space available. This meant that there was little tolerance in the layout or levels. The concept was unusual including a swale formed from tarmac within the car park (which could be driven over), to collect water and discharge it into the nearby green space. It then flowed through a series of stepped SuDS (two sub-catchments including tarmac swale, filter strips, pond components, bog garden and gravel garden). It was designed to create different habitats with slightly different water regimes. These were created in part by using different soil mixes and depths of water.



Figure 37.14 Incorrect levels meant water overflowed at the sides instead of to the SuDS garden downstream



Figure 37.15 Levels correct so water flows in the right direction

A typical challenge in some of the schools was how to create the appropriate engineered soils that were specified for the works. On this site, the existing soil was heavy London clay, so the mix was specified to be created with imported soil (rich in organic matter from a sustainable source). However, the contractor used the existing site soil, which created an unsuitable mix with large clods of heavy clay. In some locations this was sufficiently remediated by digging in organic matter, but in others, the soil had to be removed and the mix replaced.

In one location a filter drain was created to take the discharge from a downpipe, which was planted as a bog garden. This connected to a permanent pond, onto an area of damp habitat, which then overflowed into a Mediterranean gravel garden. While the layout and levels were discussed and developed with the contractor on the ground, the levels as built were not correct. In one section the water flowed backwards, overflowed and ran down the street. This section of the system had to be dismantled, the level of the outfall to the damp habitat reduced and rebuilt. There was a sense that simple ground modelling was not seen as requiring the same attention to precise detail as hard engineering, when in fact the correct levels were fundamental to the success of the scheme.



Figure 37.16 Completed pond

Lessons learnt

- The need to comprehensively check and record levels to ensure that the scheme fulfils its drainage function as designed.
- The need for good dialogue with the contractor to ensure that they fully understand how each part of the system should function.
- The need for the designer and contractor to work closely together to ensure appropriate delivery of the system.

CASE STUDY 37.4

SuDS for Schools project, Wildlife and Wetlands Trust (contd)

Hollickwood Primary School, Muswell Hill, London

Despite a full site investigation, some of the site services were in the wrong place. This-+ meant that when excavations started, the shape and location of the swales had to be adjusted on the ground by narrowing it in one location and making it slightly deeper throughout to ensure that the correct conveyance capacity was achieved. Further down the site, the excavations hit a set of concrete steps below ground, which turned out to be the entrance to the old Muswell Hill bus station air-raid shelter. As this was too difficult to remove, the scheme was adapted on the ground, with the top step becoming a weir to the detention basin, so that when it fills, it flows up and over the steps to a swale beyond. The deputy head teacher now uses this feature to teach the children about the Second World War and the importance of air-raid shelters.



Figure 37.17 Swale creation



Figure 37.18 Completed swale with a step to an old air raid shelter forming a weir to the detention basin (the top step of the air raid shelter can be seen through vegetation at the bottom left of the photograph)

Lessons learnt

- On redevelopment sites, always 'expect the unexpected', and be prepared to adapt.
- Be aware that services may not be in the expected location, even when below-ground surveys have been undertaken.
- Buried artefacts may not show up on underground surveys.

SuDS designer and site supervisor	Wildfowl and Wetlands Trust
Landscape contractors	Maydencroft Ltd, Warwick Landscaping Ltd

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Regulations

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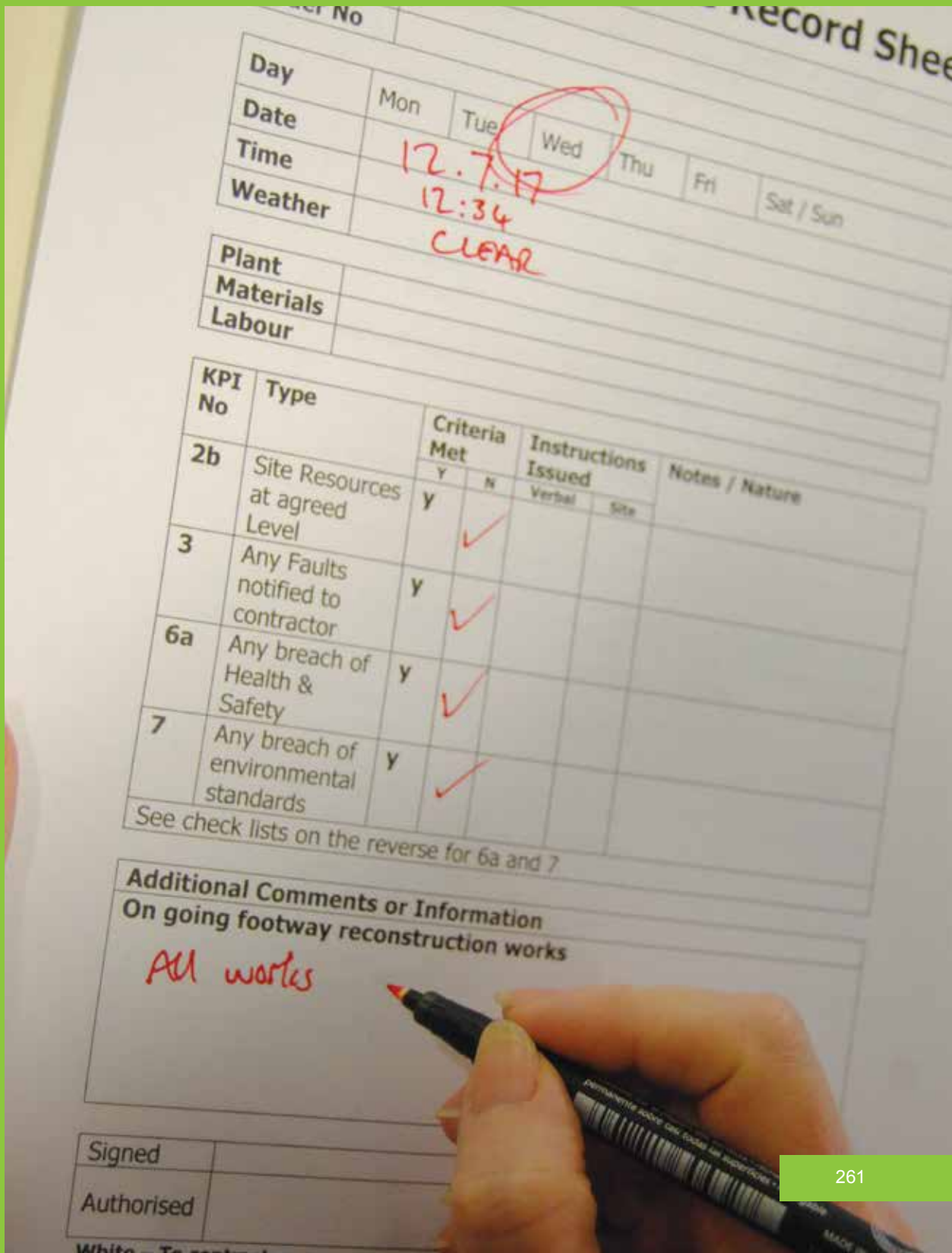
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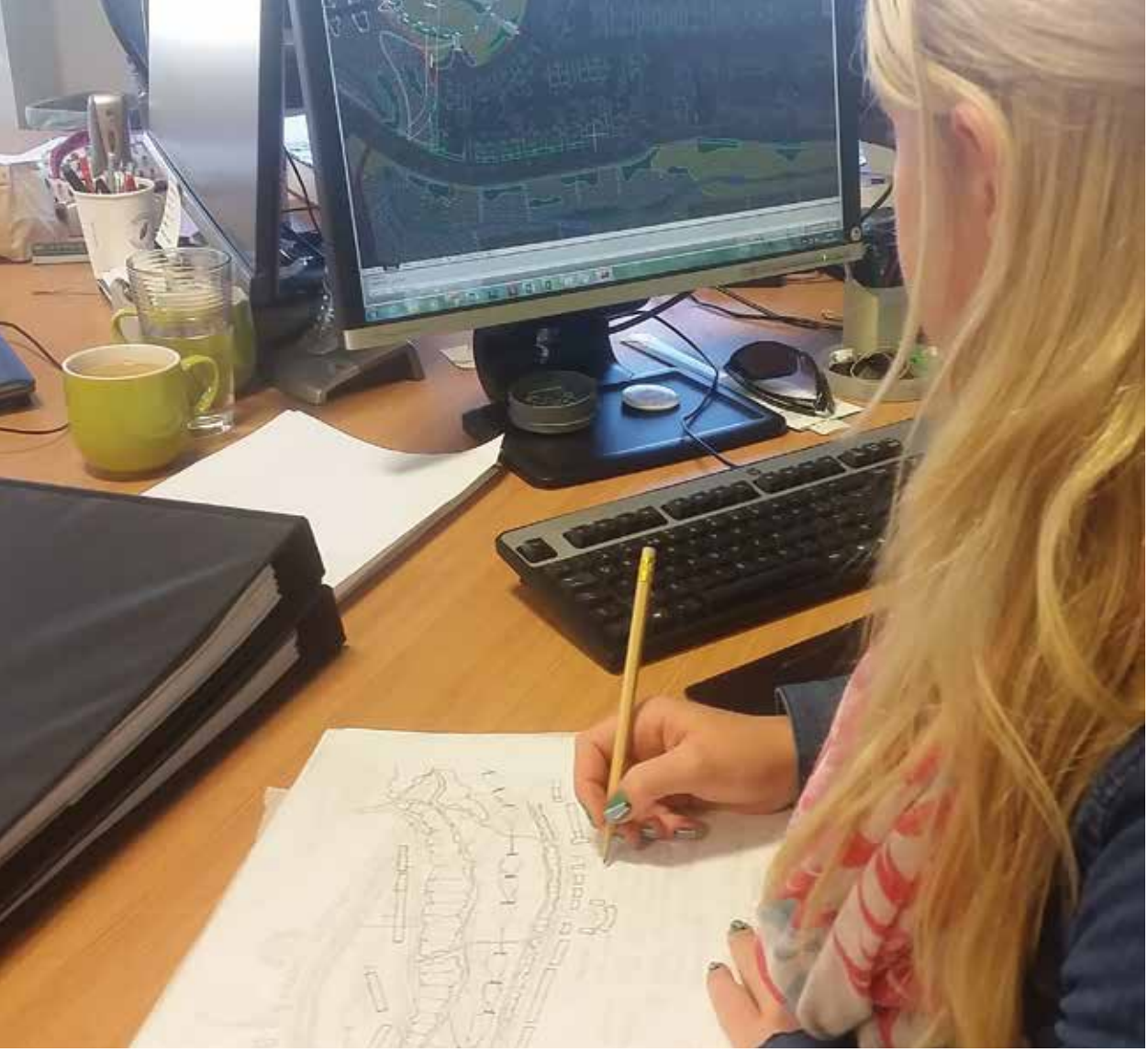
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Appendix A1

Checklists

This chapter provides a series of checklists that can be used by people constructing, managing, inspecting or approving SuDS, to ensure that all relevant design, construction and maintenance considerations have been taken into account and documented in a consistent way.

TABLE A1.1 Pre-construction checklist

	✓
Is there sufficiently detailed topographic information available about the site?	
Have all below ground services been surveyed, and is all statutory and utility provider information available?	
Are full details available of the extent or protection zones and approved protection measure for trees and habitats to be retained, or constraints around heritage artefacts or structures? Is information available regarding the restrictions of seasonal works for protected species?	
Is all information available regarding watercourses, drainage ditches or culverts, and history of flooding?	
Has the potential impact of water flow from off-site land been considered?	
Is the full site investigation report available? Does it include infiltration tests for areas designed for infiltration?	
Are any studies into the previous use of the land available (such as contamination or groundwater)?	
Are the construction drawings and specifications for all the SuDS available? Do they include full planting plans and specification? Make sure the drawings are the latest versions issued for construction and provide adequate information to allow construction.	
Do the construction drawings clearly show the management train, and whether the SuDS is an infiltration or attenuation system? Is the SuDS design report available?	
Are all levels at inlets and outlets provided along with storage volumes for each component and the permitted discharge rate from site? Are the levels in the system consistent with the level of the discharge point? Check the level of the discharge point before starting construction.	
Is the management of exceedance flows shown on the design drawings? Do they show how they interact with the main SuDS component or scheme?	
Are full contour plans (which include levels) for all ground works, banks, basins and other components provided?	
Have the designers considered the overall cut and fill requirements for the site against proposed levels?	
Are the details of specialist suppliers available, along with the manufacturer's recommended installation requirements for all proprietary products?	
Have the installation standards for all construction items been confirmed?	
Has a schedule of construction inspection checklists and hold points been compiled and agreed?	
Has it been agreed who will inspect each part of the works for each/every phase, the notice required before inspection, and what needs to be recorded (written and photographically)?	
Is the local community aware of the SuDS scheme and do they understand the approach taken?	

TABLE A1.2 Pre-construction checklist	✓
Location of soil heap is appropriate, and not subject to surface water flows, site sediments or silts	
Area for soil stockpile has been cleared of weeds and/or other site materials before depositing soil	
Weather conditions before stripping and stockpiling operations, and cease activities during and immediately after heavy rainfall	
Overall height of soil heap is no greater than two metres, profile to shed water, angle of bank slope (ideally) not greater than 1 in 2, and that it is adequately consolidated, but not compacted	
Soil heap has been sown with a ground cover, and that cover is adequate to prevent weed infestation	
Outcome of soil test before reuse and that appropriate fertilisers are used to improve the soil to the specified standard	

TABLE A1.3 Pre-construction checklist – managing erosion	✓
Planting is properly established before allowing water to drain through it or that turf is partially established and well pinned down	
Erosion control matting is used on steep slopes where problems are likely to occur	
Slopes are well prepared to receive matting	
Matting will deal with velocity of water anticipated	
Anchor trenches are used and adequately sized	
Matting is properly lapped, pinned and stapled	
Hydroseed mix and application rate is correct for site location as specified	
Slope is properly roughened to receive hydroseed	
Temporary check dams are necessary to reduce velocity during establishment	

TABLE A1.4 Pre-construction checklist – managing silt	✓
Exposed soils either in the SuDS or next to it are not washing out and causing silt problems	
Silt fences or temporary silt basins are required to manage on-site silt and provide where necessary	
Where SuDS are used to hold silt temporarily, they are cleaned out before final planting or seeding	
Protection is in place to prevent silt washing into pervious paved areas	
Protection is in place for all underground storage systems and they have provision for cleaning	
A mobile silt catchment plant is necessary	
Runoff from fresh concrete is managed to prevent damage to SuDS	

TABLE A1.5 Handover inspection checklist	✓
All changes to the designed system have not affected the ability of the SuDS to deliver the quantity/quality/biodiversity and amenity requirements as originally designed	
Inlet and outlet levels are correct	
Structural components are as specified in the design	
Slopes are constructed to the correct gradients	
Correct planting/turfing has been installed and has established	
Is there uneven settling of soil, channelling, unwanted ponding or erosion of bed or side slopes	
Is there evidence of construction sediment or unexpectedly rapid build-up of sediment	
Agreed access for maintenance is clear	
Site photographs of all key stages and a record of below ground works that are now covered up	
Test certificates	
Topographic survey of completed SuDS scheme	
Operation and maintenance plan for SuDS	
Other (TBC)	

TABLE A1.6 Soils checklist	✓
Certified analysis of soil as delivered against specification	
If analysis of site soil is required, take several samples from different areas of the site	
Each type of delivered soil is separately identified to avoid misuse	
Existing soil heaps are being managed and protected in good condition	
Delivered soils are managed/handled correctly in good condition	
Batch procedure to ensure that site-mixed soil proportions and extent of mixing is correct	

TABLE A1.7 Materials: geosynthetics and aggregates checklist	✓
Materials delivered to site conform to specification	
If on-site sampling or testing is required, take several samples from different parts of the site	
Supplier's requirements for storage, handling and installation are followed	
Requirements on certificates (eg BBA) for storage, handling and installation are followed	
Qualifications or experience of geomembrane installers	

TABLE A1.8 Inlets, outlets and flow control systems checklist	✓
Level of outlets and overflows are as specified on the design drawings	
Dimensions of outlets and flow controls are as specified on design drawings	
Flow control is from the supplier specified on design drawings (if appropriate). If not, the designer has confirmed their performance as acceptable	
Flow controls (eg vortex flow controls) are installed the right way up and in the position shown on design drawings (eg on the outlet pipe)	
Finishing of the details is as shown on design drawings (ie construction is visually attractive)	
The connection to sewer is via the demarcation manhole in accordance with WRc (2007)	

TABLE A1.9 Rainwater harvesting checklist	✓
Both the tank and the overflow are built to the correct level	
All areas planned to drain to the tanks are included	
Drainage field has right capacity for volume of drainage required	
All filters are installed correctly	
Underground tank has correct surround and bedding	
Above ground tank has stable supports	
There are no misconnections between SuDS and mains water supply	

TABLE A1.10 Green and blue roofs checklist	✓
Roof/insulation surface is clean and free of sharp protrusions that could puncture the membrane	
Roof membrane is installed as per design details and verified/tested by appropriate person as specified	
Protection layer/root barrier placed over membrane if required	
Drainage layer installed across whole of design area (do not just check at edges)	
Drainage layer is the same product as specified on design drawings and is installed the right way up	
Drainage layer connected to outlets	
Correct number, size, specification and location of drainage outlets	
Growing media as specified in design both for content and laying depths	
Growing media/substrate is correct thickness across the whole area (not just the edges)	
Mounds introduced for biodiversity or other purposes are as shown on design drawings	
Plants/seeds as specified on design drawing and at correct density, or that sedum mat is the correct thickness	
Biodiversity features are installed (eg old tree branches or logs)	
Edge drainage, border zones and fire breaks installed as per design	
An appropriate watering regime is in place to ensure the successful establishment of the plants/ seeding/sedum mat	
Ensure monitoring regime for plants is in place (to inform early decisions on performance and maintenance, and allow for the possible introduction of additional species as the roof establishes)	

TABLE A1.11 Infiltration systems checklist	✓
Excavations are to the correct design levels	
Sides and base of excavation to expose soils and check against type assumed in the design	
The base is level and suitable for construction of the soakaway tank or basin	
The area for infiltration has not been compacted. If so, rectify and re-inspect	
Soakaway units are as specified on the design drawings	
Backfill is as specified and compacted sufficiently with machinery that is not too heavy	
Basin topsoil is as specified and sufficiently permeable	
Basin planting is as specified – species, size and density	
Muddy runoff – ensure that dirt has not been allowed to enter the system. If it has, then ensure that it has been cleaned out to an acceptable standard	
The specified depth of soil in the design drawings has been placed over the top of the soakaway tank	

TABLE A1.12 Proprietary treatment systems checklist	✓
Read and follow suppliers' instructions before receiving delivery to site (ask the site manager for these if they not been provided or download from the manufacturer's website)	
Products and materials are stored on site correctly as described in suppliers' instructions	
Handle products and materials as described in suppliers' instructions	
The base of the excavation is clean and level and at correct depth	
Inlets and outlets are installed the correct way round	
Casing/chamber are installed correctly	
All seals are installed correctly	
Filters etc are installed right way round	
Water flow through the component is tested before covering it up	
Backfill is as specified on design drawings	

TABLE A1.13 Filter strips checklist	✓
For infiltration filter strips (where infiltration is required by the design), check that permeability of soils is still effective following construction	
Where specialist soils are used to promote infiltration, delivered soils comply with the specification. This may require re-testing samples from across the soil storage area	
Completed levels accord with original design drawings (see next point)	
Audit trail of changes to ensure revised scheme still fulfils requirements of the original scheme	
Size of area drained has increased (see next point)	
Sizing of filter strip has been increased to accommodate increased drainage area	
Drop from paved surface to filter strip is continuously at a level of between 50 mm to 100 mm	
Adequate 'edge protection' measures are in place to avoid vehicle overruns	
Level of filter strip is consistently between one and five per cent	
Topsoil depth is as specified	
Seed/turf mix complies with the original specification	
Vegetation is sufficiently dense to withstand water flow to allow runoff across the strip without the soil eroding before being brought into use	

TABLE A1.14 Filter drains checklist	✓
The area shown on drawings falls adequately towards the drain	
Levels in bottom of trench to ensure a continuous fall	
Adequate stone below invert of drain pipe – sized to pipe diameter	
Trench width and depth is correct	
Geotextile is as specified and has the correct porosity	
Geotextile is lapped and has no tears or damage	
Aggregates are the correct size and the material is clean and does not include fines	
Aggregate size used is in accordance with the specification	
Sacrificial layer of geotextile/stone provided if no filter strip used	
Outlet is the size as specified and is installed at the correct level	

TABLE A1.15 Swales checklist	✓
Completed levels along length of system and at weirs/outfalls agree with original design drawings, if not (see next point)	
Audit trail of changes to ensure revised scheme still fulfils requirements of the original design criteria and specification	
Gradient of side slopes and width of base to swale are as designed	
Soil permeability for infiltration swales is as specified	
Depth and cover of membrane where used are as designed	
That seed/turf mix or plants supplied complies with the original specification	
That vegetation is sufficiently dense to withstand water flow before use	
Level of grass/road edge where 'over-the-edge drainage is used is as designed	
Drainage material and pipe in under-drained swales are as specified	
Correct geotextile provided to underdrain and pipe are as specified	

TABLE A1.16 Bioretention systems checklist	✓
Where infiltration is required by the design ensure that permeability of natural soils is effective and delivers the design infiltration capacity	
Particle size of delivered engineered soils or individual soil elements for site mix comply with specification	
Depth of engineered soil is as designed/specified and undertake on-site permeability test to check soils drainage capacity	
Audit trail of changes to ensure revisions to scheme still fulfil requirements in-line with original scheme	
Graded filter or geotextile used, and compliance to specified materials/depth	
Piped drains are installed in base of system and connected to main drainage system correctly (not infiltration systems)	
Overflow system is in place, and functioning correctly	
Inspection tube installed correctly	
Plant sizes and species are supplied and located to the correct specification and design	
Organic soil mulches have not been used	
Specified components are in the correct place to break inlet velocity	
Where forebays are used, finished levels allow even flow of water into system	

TABLE A1.17 Trees checklist	✓
Runoff areas connected to each tree pit are as designed	
Soil volumes provided are as specified	
Soil mix, depth and width of installation are as specified	
Services do not conflict with tree pits, and are located outside drainage zone	
Surface of tree pit allows aeration of soil below using an aeration pipe (or other agreed means)	
Overflow pipe is provided where soils do not infiltrate	
Tree root barriers are installed where required	
Proposed and actual location of utilities are given – seek advice if within proposed SuDS area	

TABLE A1.18 Surfaces – subgrade and sub-base checklist	✓
CBR value checked when formation exposed to confirm design value	
Formation is to specified line and level	
Formation permeability has not been reduced by compaction	
Geotextile placed as per design specification with no tears or holes, and lapped correctly between sheets	
Geomembrane (if required) placed as per design specification with no tears or holes, with joints sealed as per design, and penetrations sealed with Top Hats	
Sub-base meets the specification for: • grading • porosity • hardness and durability • permeability.	
Sub-base compacted to specified density and depth and is screeded to specified line and level	
Stabilisation layer placed on top of sub-base if necessary	

TABLE A1.19 Modular permeable surfaces checklist	✓
Laying course is at design thickness	
Blocks laid and joints filled and then compacted	
Surface tolerances specified in design have been achieved	
Block pattern is as specified in design	
Edge restraint and block cutting is acceptable and as shown in design (no cut block should be less than one-third of the whole)	
Joints are full of specified jointing material	
Blocks meet requirements of specification	
Surface is clean and free draining	
Runoff from nearby soil areas cannot occur	

TABLE A1.20 Porous asphalt checklist	✓
No evidence of segregation or pooling of binder in delivery truck beds	
Asphalt meets requirements of specification	
Suitable laying machine is used	
Asphalt laid in thickness specified in design (maximum layer thickness and total thickness)	
Asphalt delivered and compacted within temperature specified in design	
Asphalt compacted in accordance with specification and to specified line and level (and correct tolerances)	
Surface is clean and free draining	
Runoff from nearby soil areas cannot occur	

TABLE A1.21 Porous concrete checklist	✓
No evidence of segregation during delivery	
Concrete meets requirements of specification	
Suitable roller screed is used as specified in design	
Concrete laid in thickness specified in design	
Contraction joints are formed by rolling or forming at spacing specified in design	
Surface is clean and free draining	
Runoff from nearby soil areas cannot occur	

TABLE A1.22 Resin-bound gravel checklist	✓
Surface is clean and free draining	
Runoff from nearby soil areas cannot occur	

TABLE A1.23 Grass reinforcement checklist	✓
Reinforcement elements are as specified in design	
Sand or gravel infill as specified in design: • permeability • organic content	
Reinforcement is placed to designed line and level	
Infill is placed to correct depth and is below top of reinforcing elements	
Correct grass or plant mix is used	
Allowance for expansion has been provided	
Surface is clean and free draining	
Runoff from nearby soil areas cannot occur	

TABLE A1.24 Attenuation storage tanks checklist	✓
Formation is to correct depth and level shown on design drawings	
Side slopes to excavation and ground conditions are as assumed in the geotechnical design report	
Base of excavation is level and firm	
Tank units are as specified and shown on design drawings (make sure correct classification or strength units have been delivered)	
Correct number and location of connecting units used and flat packed units assembled correctly	
Correct geotextile or geomembrane is as shown on design drawings, including the protection fleece if specified	
Backfill is as shown on design drawings and as specified	
Compaction of backfill with plant is as specified by the designer (ie not too heavy)	
Backfill over top of tank to depths is specified on design drawings and in the specification	
Backfill is compacted with correct plant and to the required density	
Tank is fenced off to prevent overloading by construction traffic (if necessary)	
At pre-handover inspection of tank, it should be free of silt and other debris (CCTV survey may be necessary)	

TABLE A1.25 Detention basins checklist	✓
Completed levels agree with original design drawings (if not, see next item)	
Audit trail of changes to ensure revised scheme still fulfills requirements of the original scheme	
Location, sizing and level of inlets and outlets are as design drawings	
Level of base to planted basin is consistent and no >1 in 100	
Where engineered soils are used to provide infiltration, check delivered soils comply with specification	
Seed/turf mix complies with the original specification	
The species and size of planting has not been changed (refer to the designer for suitability)	
Vegetation is sufficiently dense to withstand water flow without eroding before bringing into use	

TABLE A1.26 Ponds and wetlands checklist	✓
Land used for temporary site runoff – fully remediated before construction of pond/wetland	
Plan dimensions, depths and levels throughout including inlets and outlets agree with original design drawings	
Audit trail of changes to ensure revised scheme still fulfils requirements of the original scheme	
Size of area drained has not increased from that specified or designed	
Banks and benches are constructed to widths and gradients specified	
Liners are installed, sealed and protected as specified	
Inlets control water velocity to provide slower flows and provide forebays for sediment where specified	
Inlets and outlets are protected from blockage by debris and silt build-up	
Plants and species are supplied to size/form as specified before planting	
Plants set out and planted in accordance with the specification	
Agree how successful natural regeneration is to be approved, and agree supplementary planting/ change to management approach	
Agree remediation measures for areas of erosion	

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November 2017

Over recent years SuDS delivery in the UK has steadily increased. This has improved knowledge and experience particularly around the construction of SuDS. This guide uses that experience to help those who are constructing SuDS to understand and avoid common pitfalls.

The guide starts with considering SuDS in the construction planning and management of a site. It discusses the construction of different SuDS components, using photographs of actual site works to illustrate both good practice and what can go wrong. Case studies are provided to show how good construction has been achieved or problems resolved.

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